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Interdisciplinary Knowledge Sharing in Production Planning

Communities of Practice in Contractor Organizations for Metro Construction in Tunnel Projects

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Title	Interdisciplinary Knowledge Sharing in Production Planning: Communities of Practice in Contractor Organizations for Metro Construction in Tunnel Projects
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Abstract

Production planning in construction projects has a dual nature. While it relies on formal procedures, structured routines and visual tools, it is equally shaped by tacit knowledge – personal experience, judgment and intuition – which is the lifeblood of interdisciplinary coordination. Nonetheless, planning practices often remain fragmented, as tacit knowledge continues to be overlooked despite its central role in daily coordination. This Master Thesis addresses these fragmentation challenges, exploring how tacit knowledge sharing occurs within contractor organizations, aiming to enable proactive planning in metro tunnel project environments. The study builds on two ongoing metro projects in Sweden: an in-depth case study complemented by additional interviews from a second project. Through a qualitative research design, grounded in the Communities of Practice framework, production planning practices, sequencing routines and interdisciplinary dialogues are examined. The findings show that the implementation of collaborative tools for proactive planning depends not only on structural support but also on organizational culture, shaped by emotional ownership, mutual understanding and informal learning. However, results also reveal that for proactive production planning, knowledge sharing must be channeled through a designed structure that regulates interactions among individuals and collaborative practices. The research contributes theoretically by adapting the Communities of Practice framework to high uncertainty and fast-paced construction environments, and practically by proposing strategies to sustain collaborative planning routines.

Titel	Tvärdisciplinärt kunskapsutbyte i produktionsplanering: Praktikgemenskaper i entreprenörsorganisationer för tunnelprojekt inom tunnelbanebyggen
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Sammanfattning

Produktionsplanering i byggprojekt har en dubbel natur. Den bygger dels på formella rutiner, strukturerade arbetssätt och visuella verktyg, men formas samtidigt av tyst kunskap – personlig erfarenhet, omdöme och intuition – som utgör själva livsnerven i den tvärdisciplinära samordningen. Trots detta förblir planeringspraxis ofta fragmenterad, då tyst kunskap fortfarande är underskattad och undervärderad, trots dess centrala roll i det dagliga samordningsarbetet. Denna uppsats behandlar dessa fragmenteringsutmaningar genom att undersöka hur tyst kunskap delas inom entreprenörsorganisationer för att möjliggöra en mer proaktiv produktionsplanering i tunnelbanemiljöer. Studien baseras på två pågående tunnelbaneprojekt i Stockholm: en djupgående fallstudie som kompletteras av ytterligare intervjuer från ett andra projekt. Med hjälp av en kvalitativ forskningsdesign, grundad i teorin om Communities of Practice (praktikgemenskaper), analyseras produktionsplaneringens arbetsrutiner, sekvensering och tvärdisciplinära dialoger. Resultaten visar att införandet av samarbetsverktyg för proaktiv planering inte enbart är beroende av strukturellt stöd, utan också av organisationskultur – präglad av emotionellt engagemang, ömsesidig förståelse och informellt lärande. Studien visar dessutom att för att möjliggöra proaktiv produktionsplanering måste kunskapsdelningen kanaliseras genom en medvetet utformad struktur som reglerar interaktioner mellan individer och samarbetspraktiker. Avhandlingen bidrar teoretiskt genom att anpassa ramverket Communities of Practice till osäkra och snabbrörliga byggmiljöer, och praktiskt genom att föreslå strategier för att upprätthålla samordnade planeringsrutiner.

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Lorenzo Racchi

Stockholm, 26.05.2025

“Do not observe yourselves too much, do not draw conclusions too hastily about what is happening to you; simply let it happen to you. Your past takes part in everything that is happening to you now.”

“What we call destiny comes out of people, it does not enter them from the outside.”

(Rainer Maria Rilke)

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1 INTRODUCTION

This chapter introduces the Background, Problem Statement, Aim and Research Questions that guide the study. It defines the reasons behind the study and outlines the challenges addressed within production planning in infrastructure projects.

1.1 Background and Context

The transportation ecosystem depends on road and railway infrastructure to support connections between and within cities, regions, and nations. The construction sector plays a critical role in sustaining these links, which are fundamental to business continuity and economic development. In 2022, the construction industry contributed over €1,158 billion to the EU economy—representing 9.6% of the EU total—and employed nearly 25 million people (European Commission, 2021).

The sector is undergoing a significant transformation to align with the European Green Deal, which targets climate neutrality by 2050 (European Commission, 2021). The Sustainable Urban Mobility Planning (SUMP) framework calls for a 90% reduction in transport-related greenhouse gas emissions, while the EU Urban Mobility Framework prioritizes more sustainable transport systems (European Commission, 2021). Tunnel infrastructure projects are central to these strategies, as they help expand urban mobility networks, reduce congestion, and address the challenges of rapid urban growth (Wei et al., 2024a).

In Sweden, Stockholm metropolitan area is extending its metro system to improve accessibility and reduce CO_2 emissions. Several tunnel projects are currently underway, including extensions of the blue and green metro lines that will connect newly developed residential districts aiming to reduce traffic congestion ("Nya Tunnelbana," n.d.). This study focuses on two project organizations involved in the blue line extension, for anonymity they are referred to Metro Project 1 (MP1) and Metro Project 2 (MP2).

Delivering complex underground infrastructures, such as metro tunnels and their underground constructions, requires more than just technical expertise, it depends on advanced coordination across disciplines, efficient planning, and cost and time effective execution strategies (Sharafat et al., 2021; Wei et al., 2024). These demands highlight the need for collaborative and proactive production planning approaches, such as Pull-Planning, which aims to anticipate issues in the construction site, streamline sequencing and ensuring construction readiness (Ballard, 2000; Garcia-Lopez and Fischer, 2024). However, to effectively implement such collaborative methodologies is not just a matter of tools or procedures, but it requires a deeper understanding of how project teams operate in practice (Ballard, 2000). Contractor project teams are key actors in shaping production planning outcomes, and their internal dynamics influence how planning tools are adopted, adapted or resisted on site.

1.2 Problem Statement

In construction project management, production planning and execution are closely intertwined as they occur simultaneously, making planning activities continuously adapt to real-time progress (Kim et al., 2015; Garcia-Lopez and Fischer, 2024). Production planning focuses on preparing and coordinating construction flows - such as labour, material, equipment, workspace and information - to ensure smooth start and execution of activities. However, the effectiveness of this coordination depends on more than just formal procedures and scheduling tools (Ballard, 2000; Wei et al., 2024a).

Production Planning presents a dual nature: while it relies on structured methods, formal routines and visual tools, it is also deeply rooted and shaped by tacit knowledge - personal experience, intuition and judgement of production team members (Nonaka, 1998; Gustafsson and Lindahl, 2017). These human and informal aspect play a critical role in handling uncertainties and interdependencies in fast changing environments like metro tunnels and their underground constructions.

Given the central role of tacit knowledge, production planning remains fragmented and challenging to formalize. Several recurring issues identified in the literature hinder effective planning and knowledge sharing in metro tunnel and underground construction projects:

- High uncertainty due to soil and groundwater conditions (Wei et al., 2024a),
- Logistical challenges in narrow underground spaces (Gidado, 1996),
- Siloed team structures and disciplinary fragmentation (Soomro et al., 2024),
- Disconnection between planning schedules and field execution (Kim et al., 2015),
- Time pressure and organizational turnover limiting trust and long term collaboration (Schenkel and Teigland, 2008).

Lean Construction offers methods like the Last Planner System, with its Pull-Planning mechanism, to support proactive and collaborative planning (Ballard, 2000; Garcia-Lopez and Fischer, 2024). However, implementing such systems in practice is often constrained by organizational culture, knowledge siloes, and the undervaluation of tacit knowledge and its interdisciplinary sharing (Gustafsson and Lindahl, 2017; Soomro et al., 2024). Visual tools and digital systems may improve information flow, however they don't automatically capture the informal, experience-based practices that shape daily coordination and planning decisions (Lin and Golparvar-Fard, 2021; Sacks et al., 2010).

Therefore, to enhance proactive production planning in complex infrastructure environments, it requires to move beyond prescriptive methodologies and explore how planning is actually managed within contractor project teams (Ballard, 2000). This includes examining formal and informal planning practices and how tacit knowledge is shared across disciplines. A better understanding of these dynamics is essential for developing planning practices that are both structurally and socially embedded.

1.3 Research Aim and Research Questions

Following Lean Construction principles of learning and continuous improvement and situated learning theory, this study aims to *understand how knowledge sharing practices enable more proactive production planning within infrastructure project teams.* This research aims to fulfill its purpose by answering to the following research questions:

i. How does interdisciplinary coordination happen in production planning processes within project teams?
ii. How does interdisciplinary tacit knowledge sharing happen during production planning in construction project teams?
iii. How can knowledge sharing practices enable a more proactive approach to production planning?

1.4 Significance of the Study and Limitations

This study contributes to both theory and practice by addressing the research gap in qualitative studies of metro construction in tunnel project management. Specifically, it focuses on the contractor production teams of two ongoing metro tunnel projects in Stockholm revealing how planning depends not only on formal tools but also on tacit knowledge. The findings highlight the importance of sequencing routines, interdisciplinary planning and visual communication in enabling collaborative planning practices, like Pull-Planning.

By using the Communities of Practice framework offered by Wenger (1998), the study offers a structured lens to understand how learning and coordination emerge through shared routines and mutual engagement. These insights can support contractor organizations and project managers in setting up environments that combined structure and flexibility, ensuring that technical workflows and informal tacit knowledge are valued and integrated.

However, the research has some contextual limitations. It is based on two metro tunnel projects executed by the same contractor in Sweden, which may limit the generalizability of findings to other types of projects, or geographic regions. Moreover, the research reflects a snapshot in time, relying on interviews observations and one questionnaire, without evaluating long-term outcomes or software systems.

2 LITERATURE REVIEW

This chapter reviews existing research in construction project management, focusing on production planning and knowledge sharing within complex infrastructure projects. It identifies key themes and gaps that shape the foundation of this study.

2.1 Production Planning in Complex Projects

Metro tunnel and their underground construction projects are inherently complex due to geological unpredictability, long durations, logistical constraints and the temporary nature of project organizations (Sharafat et al., 2021; Wei et al., 2024a). Poor project management further amplifies these issues, leading to waste and reduced productivity (Rathnayake et al., 2023). Given these challenges, effective Construction Project Management plays an essential role in monitoring and ensuring timely project delivery for complex projects such as tunnels and metro projects (Sharafat et al., 2021).

Production planning serves as the bridge between project planning and on-site execution. Its main function is to coordinate construction flows, defined as "a series of inputs necessary for an activity to start" (Koskela, 1999: Garcia-Lopez and Fischer, 2024). In tunnel projects, activities such as excavation, jet grouting, or concrete pouring depend on the timely readiness of these flows. Production managers are responsible for ensuring all inputs are in place: confirming that precedent activities are complete, workspaces are cleared, materials and equipment are available, teams are informed etc. (Koskela, 1999; Garcia-Lopez and Fischer, 2024). In short, production planning routines are designed to coordinate and prepare activities so that execution can proceed smoothly, by continuously updating work progresses.

2.1.1 Interdisciplinarity Complexity and Challenges in Production Planning

Production planning and execution are interconnected processes that must operate continuously and sequentially to ensure project delivery (Kim et al., 2015; Garcia-Lopez and Fischer, 2024). As the link between strategic planning and on-site implementation, production planning translates planning strategies into action while aiming to meet the planned time, cost and quality. However, this dual role naturally brings significant challenges.

Large infrastructure projects involve many interdependent tasks from various disciplines. When these activities are performed in isolation, without considering their interdependencies, projects risk inefficiencies such as delays, rework, and missed deadlines (Kim et al., 2015). Consequently, recognizing and managing these interrelationships is essential to reduce fragmentation, group related tasks, and improve productivity in line with Lean Construction principles (Ballard, 2000; Kim et al., 2015).

Project complexity further complicates planning. Gidado (1996) defined project complexity as the difficulty level of implementing a planned production workflow strategy in relation to any quantifiable objectives. Whether caused by organizational, technical, or resource-related factors, this complexity makes production planning inherently difficult (Gidado, 1996; Fewings, 2019;). In addition, traditional production control

systems tend to be reactive. They rely on progress tracking and corrective measures after problems arise, rather than preventing issues in advance (Ballard, 2000; Garcia-Lopez & Fischer, 2024). Physical site constraints also make it difficult to capture and share accurate status updates, often disconnecting planning from the actual schedule (Lin and Golparvar-Fard, 2021). This disconnection can cause cascading delays throughout the project lifecycle (Rathnayake et al., 2023).

To address these issues, Lean Construction promotes proactive production planning through systems such as the Last Planner System (Ballard, 2000). However, the success of such standardized processes ultimately depends on human factors, particularly interdisciplinary knowledge sharing between team members from different fields (Soomro et al., 2024).

2.1.2 Pull-Planning as a Collaborative Mechanism in the Last Planner System

The Last Planner System (LPS) aims to increase efficiency and productivity, shifting from reactive to proactive production planning. While traditional project control tracks progress and applies corrections once deviations occur, a "lookahead" approach identifies and solves potential issues in advance, considering site conditions and team capacity for more realistic and reliable commitments (Koskela, 2000; Ballard, 2000).

Part of LPS, **Pull-Planning** is a collaborative visual method that helps teams "pull" tasks into the schedule only when they are ready to be performed, rather than pushing tasks forward based on fixed deadlines. It works around a "need–delivery" logic: teams identify what inputs are needed from others to perform a task and commit to deliver them. This collaborative way of planning supports production managers to reflect and articulate their knowledge, coordinate commitments and align disciplines by making preparatory needs explicit and promoting discussion across teams through visual whiteboards and colored sticky notes. This helps avoid last-minute surprises, improve coordination, and build trust among members (Ballard, 2000; 2002).

However, by understanding the organizational culture and production planning routines, engagement, collaboration and innovative thinking environment must be ensured for implementing Pull-Planning into teams as intended (Ballard, 2000; Garcia-Lopez and Fischer, 2024).

2.2 Knowledge Sharing and Organizational Learning in Project-Based Construction Planning

Gustafsson and Lindahl (2017) point out the dual nature of production planning, challenging the idea of rigid schedules and predefined tasks in favor to tacit knowledge. While formal procedures guide project control, production teams rely on tacit knowledge - built on intuition, judgment, and experience - to handle uncertainties (Davenport and Prusak, 1998; Nonaka, 1998). Hence, for improving production planning routines its dual nature must be recognized, precisely structured processes must be supported by knowledge-sharing practices for tacit knowledge to be visible and actionable (Davenport and Prusak, 1998).

2.2.1 Tacit and Organizational Knowledge in Production Planning

Understanding how production teams function in complex infrastructure projects requires a deeper examination of the human dimension of planning. In dynamic environments such as tunnel construction, much of the coordination, problem-solving, and decision-making relies not only on formal procedures but also on

experience-based knowledge. Nonaka (1998) distinguishes between explicit and tacit knowledge. Explicit knowledge is formal, systematic, and can be easily accessed, communicated and shared. With appropriate care, it can be exchanged much like information.

Tacit knowledge consists of personal technical skills, mental models, and beliefs which are so ingrained that are taken for granted and not articulated (Nonaka, 1998). Known also as "know-how", it is embedded in practice and only becomes explicit when externalized through reflection or interaction (Nonaka, 1998). People's actions and decisions-making are governed by tacit knowledge, as it is deeply embedded in experience, intuition, and judgement. From this point onward, the terms "knowledge" and "tacit knowledge" are used interchangeably, as tacit knowledge is the focus of this study.

Davenport et al. (2005) explain that knowledge derives from information, that in turn evolve from data. What distinguishes knowledge is that it enables people to apply judgment, connect ideas, and act meaningfully based on experience, as it judges itself, grows, changes and develops. Knowledge is shaped through ongoing interaction with the environment: experience and judgment accumulate making knowledge capable of dealing with complexity (Davenport et al. 2005). Moreover, Davenport and Prusak (1998) emphasize that experience plays a central role in shaping knowledge, as people absorb knowledge over a lifetime from courses, books, mentors, informal learning, and personal events. Values and beliefs also influence how knowledge is interpreted and applied, both at the individual and organizational levels.

While, tacit knowledge remains embedded into people, **organizational knowledge** consists of the formal routines, practices, and norms shared among people within a company or project team. These practices are often implicit and based on accumulated experience, rather than formalized procedures (Davenport and Prusak, 1998; Nonaka, 1998).

In short, production planning does not only rely on formal procedures but also on tacit knowledge embedded in individuals, that grouped make organizational knowledge. Hence, tacit knowledge must be identified and captured into the organizational domain creating continuity across project-based environments for long-term competitive advantage (Gustafsson and Lindahl, 2017; Soomro et al. 2024).

2.2.2 Tacit Knowledge Sharing for Collaboration in Production Planning

Learning is essential for project-based organizations as it helps develop organizational knowledge. In these environments, the goal of knowledge management is to transfer insights across projects and develop organizational knowledge that supports long-term competitive advantage (Soomro et al., 2024). Achieving this, however, requires comprehensive knowledge sharing practices that enable learning within teams and promote legitimacy and participation among team members (Lave and Wenger, 1991; Gustafsson and Lindahl, 2017).

Knowledge sharing is the voluntary and conscious act of making tacit knowledge available to the other team members, who can understand, absorb and use it (Ipe, 2003). It occurs when communities are brought together by common interests and have enough knowledge, through interactions - such as informal conversation, email

or social networks – that enable cyclical feedback, stimulating collaboration and creating new knowledge (Wenger, 1998). It is important to differentiate knowledge sharing from knowledge exchange and knowledge transfer, which describe the movement of knowledge between larger entities within organizations or between organizations. In contrast, knowledge sharing is exclusively between individuals (Ipe, 2003).

In the context of production planning, knowledge sharing is particularly important, as it enables coordination and collaboration across temporary and interdisciplinary project teams (Soomro et al., 2024). Effective knowledge sharing happens when there is full mutual understanding, preventing miscommunication, inefficiencies, improving interdisciplinary alignment. Accordingly, Ballard (2000) emphasized that collaborative tools, like Pull-Planning, depend heavily on an innovative and collaborative team environment in which tacit knowledge is openly shared across disciplines. Because production planning involves high levels of interdependency and unpredictability, team members must often rely on improvisation and experience, making a climate of collaboration essential (Ballard, 2000; Koskela, 2000).

The literature suggests that knowledge sharing, collaboration and innovation are deeply interrelated. Sackmann and Friesl (2007) argue that knowledge sharing is the foundation that promotes both an innovative thinking environment and collaboration. These factors, in turn, lead to continuous improvement and learning, key goals for managers aiming to develop organizational knowledge (Davenport and Prusak, 1998; Lin and Wang, 2019; Soomro et al., 2024). When such conditions are sustained, new knowledge – understood as innovation - emerges within the organizational domain. As knowledge is generated through interactions, new knowledge generation embeds learning processes (Nonaka; 1998).

2.2.3 Situated Learning and the Social Creation of Knowledge

Knowledge sharing and learning are strictly intertwined, hence learning must also be defined and understand, as it is essential for creating organizational knowledge. In fact, learning is a social phenomenon that occurs through interactions, and the concept of **situated learning** further supports this view (Lave and Wenger, 1991).

Learning is not only absorption of information, but a social process where participation in shared practices enables newcomers to gradually join and contribute to the group (Lave and Wenger, 1991). In this framework, knowledge is not transferred but developed through active participation and mutual engagement. Through learning, successful organizations consistently create new organizational knowledge and disseminate it throughout the entire organization, quickly translating it in new technologies, processes and products (Nonaka, 1998). Accordingly, Davenport and Prusak (1998) emphasize that organizational knowledge is essential for shaping how firms operate and adapt over time. However, creating knowledge is not straightforward or an easily sustained process as it requires both formal structures and social commitment (Davenport and Prusak, 1998; Nonaka, 1998; Wenger, 1998).

According to Wenger (1998), the process of knowledge creation occurs through knowledge sharing within **Communities of Practice**, where individuals' identity and commitment to shared goals are key drivers of participation and innovation. Based on situated learning, Wenger (1998) also stresses that members' sense

of personal identification with the organization is essential. This alignment motivates individuals to contribute to learning processes, reinforcing both individual growth and collective knowledge development.

In short, when teams share a common mission and have enough overlapping expertise, their continuous interaction often generates new knowledge (Nonaka, 1998). These processes require time, space, and leadership support, consequently knowledge sharing practices must be developed and guaranteed by organizations to ensure competitive advantage (Wenger, 1998; Lin and Wang, 2019). Managers play a key role in enabling this by allocating resources, recognizing learning efforts, and embedding knowledge-sharing practices into the organizational routine (Nonaka, 1998).

2.2.4 **Structure Knowledge Sharing: Balancing Formal Structures and Informal Systems**

Although knowledge creation processes are often dynamic, tacit, context-specific and difficult to formalize, they are essential for building organizational learning and capability (Davenport and Prusak, 1998; Nonaka 1998). While informal knowledge sharing policies and processes are crucial for creating space for innovative thinking, some level of **formalization** is necessary to ensure oversight, consistency, and coordination (Davenport and Prusak, 1998). Informal, self-organizing networks can generate and share knowledge through unstructured processes, but over time these practices should be integrated into structured routines for capturing organizational knowledge (Davenport and Prusak, 1998).

A structured approach to knowledge sharing is particularly important in production planning, where poor coordination can lead to rework, delays, or safety issues (Ballard, 2000; Rathnayake et al., 2023). Shared systems help reduce errors, improve decision-making, and ensure that lessons are retained within and across project teams. Additionally, for enabling and sustaining a culture of knowledge sharing in construction teams, Soomro et al. (2024) suggest that shared leadership combined with strong open-mindedness norms helps breaking down potential silos and promoting learning and innovation.

According to Lin and Wang (2019), a climate of knowledge sharing should be established from the creation moment of the team by promoting knowledge redundancy and overlapping between experts. This establishes the perfect ground for enhancing knowledge creation and sharing. Other key enablers include psychological safety, self-efficacy, and social identification. Ishdorj et al. (2024) suggest that these elements create a supportive atmosphere where people feel safe to share knowledge and ask for help. Incentive policies that create extrinsic motivation can further encourage sharing behavior. Additionally, Shahzad et al. (2024) add that trust, diversity and inclusion establish a natural supportive learning environment.

In conclusion, formal knowledge-sharing strategies must be supported by human-centered practices. Managers should take an active role in designing interdisciplinary exchange channels that are practical, inclusive, and aligned with production planning goals. Visual communication tools can play a central role in these efforts by making knowledge more transparent and actionable (Lin and Golparvar-Fard, 2021).

2.2.5 The Role of Visualization in Knowledge Sharing

Visual communication plays a critical for enabling knowledge sharing. Accordingly, Lin and Golparvar-Fard (2021) observe that while face-to-face meetings without visualization tools are often less effective, content-specific visualizations enhance mutual understanding.

According to Hou and Pai (2009) figurative and visual language is more direct, user-friendly, and effective, particularly in fast-paced or interdisciplinary environments. It allow teams to better organize and interpret information by making abstract or complex content more concrete: diagrams, tables, and visual maps clarify relationships between tasks, roes, and timelines (Fischer et al., 2002; Hou and Pai, 2009). This effectiveness is rooted in cognitive science: the human brain naturally understands and recalls visual information more quickly than text, as it significantly boosts comprehension and participation (Fischer et al., 2002; Hou and Pai, 2009). Fischer et al. (2002) suggest that content-specific visualization based on mapping techniques can facilitate collaborative learning, as it helps individuals structure their thoughts, relate theoretical concepts to practical tasks, and engage in more meaningful conversations.

In summary, visualization supports knowledge acquisition and sharing by translating tacit insights into external and sharable formats. Specifically, in collaborative learning contexts, knowledge visualization stimulates discourses, enhances knowledge recognition and facilitates knowledge sharing and acquisition by making abstract concepts more tangible and accessible (Fischer et al., 2002; Hou and Pai, 2009).

2.2.6 Barriers to Knowledge Sharing in Construction Project Organizations

Client companies typically hire contractors to execute construction works, resulting in temporary, fragmented and interdisciplinary project organizations (Fewings, 2019). This organizational setup introduces several structural and cultural barriers to effective knowledge sharing. One of the major structural challenges is the **siloed structured nature** of project teams. Knowledge remains embedded within speciliazed disciplines, such as architecture, civil engineer and geotechnical work, limiting cross-functional learning and collaboration (Lin and Wang, 2019; Soomro et al., 2024). This natural fragmentation reduces the opportunities for collaborative problem-solving and innovation (Fewings, 2019).

Another inherent challenge is the **temporary nature** of project teams. Because team members often rotate between projects, long-term trust and continuity are difficult to establish (Lin and Wang, 2019). As a result specialized knowledge is treated as personal expertise, leading **lack of trust** and reluctance in sharing them openly (Soomro et al., 2024). Moreover, cultural factors also play a role. A **lack of standardized processes** often results in inconsistent knowledge-sharing practices making knowledge difficult to systematically capture or transfer (Ballard, 2000; Ishdorj et al., 2024).

From the literature it is suggested that to overcome these issues, construction firms must actively promote and sustain innovative thinking by implementing structured knowledge-sharing mechanisms, creating safe spaces for collaboration and encouraging early interdisciplinary communication when project teams are first formed (Ishdorj et al., 2024; Shahzad et al., 2024; Soomro et al., 2024).

2.3 Literature Gap and Research Aim

Current research has extensively focused on digital tools and technologies, such as BIM and 4D visualization, in construction project management (Wei et al., 2024). While these technologies enhance visualization and data integration, they offer limited insight into the human, social, and tacit dimensions of planning processes especially within complex infrastructure projects.

In particular, there is limited understanding of how tacit knowledge sharing supports proactive production planning and coordination among construction project teams (Soomro et al., 2024). Since production planning involves integrating multiple disciplines, its effectiveness depends not only on structured tools but also on individuals' ability to communicate, share experience, and adjust to uncertainty collaboratively.

This gap is especially evident in tunneling and underground infrastructure projects, which involve high uncertainty due to site-specific conditions and logistical constraints. As Wei et al. (2024) note, these projects require a deeper understanding of how managers adapt to uncertainty and coordinate work across disciplines. Yet current research has not sufficiently explored these informal, practice-based aspects. Moreover, little is known about how such knowledge-sharing processes unfold in the Swedish construction context, particularly in metro tunnel projects, where coordination across temporary and shifting teams is essential.

This study aims to fill these gaps by understanding how knowledge sharing can enable proactive production planning within infrastructure project teams. Drawing on Lean Construction principles and situated learning theory, the research analyzes how team members engage in planning and interdisciplinary coordination practice. The study focuses on two ongoing metro tunnel projects in Stockholm, both executed by the same contractor. Through interviews with production managers and field observations, the research aims to provide practical insight into the collaborative practices that support effective planning and execution in tunneling environments.

3 THEORETICAL FRAMEWORK

This chapter presents the analytical lens applied throughout the research for interpreting the empirical findings. The study is grounded in the Communities of Practice framework, which provides a structure to examine learning, coordination, and shared routines in project teams.

3.1 Lean Construction Principles as Research Starting Point

In construction project environments, production managers heavily rely on their experience and professional judgment, often operating with fragmented and separated schedules and undefined task structures (Garcia-Lopez and Fischer, 2024; Soomro et al., 2024). While this approach ensures flexibility and personalization to production planners, it can also limit smooth execution and hinder the flow of knowledge across disciplines, by making it harder for managers to capture. To address these challenges, knowledge sharing practices must be actively facilitated and supported by standardized and collaborative approaches.

Lean Construction through the LPS, and its Pull Planning method, introduces standardized yet adaptable procedures that promote collaboration and workflow visualization while supporting an extensive interdisciplinary knowledge sharing (Koskela, 1999; Ballard, 2000). This research conducts an in-depth social analysis that support the implementation of Pull-Planning mechanism in production planning practices and routines. These practices in this research are examined through the theoretical concept of Communities of Practice (CoP), as it provides an analytical lens to understand how shared practices, interdisciplinary coordination and informal learning evolve within organizational settings through knowledge sharing (Wenger, 1998).

3.2 Challenges of Applying Lean Construction in Project Environments

While Lean Construction principles provide valuable foundations for enhancing production planning, their application in practice presents significant challenges. Acknowledging and understanding them is essential to appreciate why additional theoretical support is necessary for analyzing knowledge sharing and planning practices in construction environments.

Lean theories are grounded on principles that tend to be over-idealistic, prescriptive and highly structured, which makes them difficult to implement in high uncertainty environments, such as construction metro projects characterized by fragmentation, delays and complex interdependencies. These features eventually undermine the planning process by causing misaligned goals and mistrust (Soomro et al., 2024). Particularly in these environments, implementing Pull-Planning requires extensive training, efforts and time for practitioners, as it strongly relies on transparent collaboration, shared responsibility, and trust among participants (Ballard, 2000).

Another challenge lies in the assumption that everyone can and will share relevant knowledge, however, knowledge sharing is shaped by individual culture, willingness, and personal interests especially in projects composed of actors from different companies (Ipe, 2003). Furthermore, not all knowledge can be easily shared, transferred, or visualized through Lean tools, mostly when it is tacit knowledge. Finally, without recognizing

that production planning is a human activity based on intuition and experience, the application of Lean Construction principles may fail to formalize and rationalize the planning processes and ignore the informal nature of knowledge sharing processes. Resulting in rigid workflows that don't capture the "soft" dimensions of planning and alienate workers (Gustafsson and Lindahl, 2017).

For these reasons, Communities of Practice will support this research in conducting a thorough analysis of the organizational and social processes underlying knowledge sharing in production planning project organizations.

3.3 The Analytical Lens: Communities of Practice

Given the challenges faced when applying Lean Construction principles in fragmented and uncertain environments, this research adopts the concept of Communities of Practice (CoP) as analytical lens. CoP theory provides a deeper understanding of how knowledge sharing, collaboration, and learning processes unfold in project-based organizational settings such as construction sites.

In recent years, researchers and practitioners have been increasingly advocating Communities of practice as essential building blocks of business knowledge economy. In fact, knowledge management becomes of primary importance when people's experience, judgement and competences are central in high uncertainty environment. Therefore, managers should include tacit knowledge within the organizational domain to uncover and capture it for facilitating learning and knowledge sharing practices with standardized yet collaborative approaches (Gustafsson and Lindahl, 2017). Undoubtedly, learning is essential for project-based organizations, such as construction contractors, where knowledge management scope is learning across projects to create organizational knowledge for competitive advantage (Soomro et al., 2024). The following section will describe the CoPs, the theory on which they lie and how they will be implemented in the study.

3.3.1 Situated Learning, Dimensions and Dynamics of Communities of Practice

To fully understand the foundations of Communities of Practice, it is necessary to first explore the theory of situated learning. Situated learning redefines how learning is conceptualized, shifting attention from individual mental activities to collective social practices where knowledge is co-created and shared (Lave and Wenger, 1991).

Learning has a central role for knowledge management in construction companies. However, according to Lave and Wenger (1991) its concept has been shifted from a mental activity that occurs within individuals to a relational and participatory model called situated learning. In fact, learning shifted from being internalization of knowledge to a social phenomenon that happens through communities' interactions, involvement and participation, where knowledge sharing is at its fundaments. Learning occurs through legitimate peripheral participation (LPP) in communities of practice, which is a process where newcomers become part of the community by engaging in its practices over time, and through legitimization they build identity (Lave and Wenger, 1991). This makes Communities of Practice grounded in situated learning.

Communities of practice (CoPs) are self-organizing groups of individuals who share a common interest, a set of problems or passion for a specific topic and who deepen their knowledge and expertise through regular interaction with ongoing basis. They are defined by common participation and not by organizational structures or formal memberships, additionally they organically shape and evolve as people engage in activities and develop a collective identity around their practice. CoPs define themselves along three dimensions summarized in Table 1. Specifically, CoPs differentiate from teams (dependent on tasks), business units (dependent on hierarchy) and networks (focused on relationships) as they are defined by *shared knowledge* and *identity*. Members engage in CoP because participation is meaningful and valuable to them not because they are required to, and participation legitimates them to be part of it. However, participation can vary in intensity and form, ultimately members are not necessarily bound and the climate is not necessarily harmonious (Wenger, 1998).

Dimension	Focus	Description
Domain	What CoP is about	The shared area of interests and/or competences that provides identity and focus, as understand and continuously renegotiated by its members
Community	How CoP function	Mutual engagement between members that bonds them together into a social entity
Practice	What capabilities CoP has produced	Shared repertoire of communal resources, such as routines, tools, languages and ways of doing things that members developed over time

Table 1- Dimensions of Communities of Practices (Wenger, 1998)

CoPs are emergent and informal structures where knowledge is created as individuals share it through collaborative mechanisms. Which makes members cultivate identity and build cohesiveness, providing basis for effective learning. However, creation, diffusion and application of knowledge is situated, therefore CoP heavily depends on the practice environment (Bresnen et al., 2003a). CoPs are nodes for exchanging and sharing knowledge across formal boundaries, ultimately routinizing and adapting it to the context and to its practitioners. Additionally, they steward competencies for driving development and innovation collaboratively through a sense of identity, and finally, stimulate professional identity and social belonging for stimulating internal learning (Wenger, 1998).

3.3.2 Role and Limitations Communities of Practice in Construction Project Environments

In construction project settings, where organizations are temporary and workflows are highly interdependent, Communities of Practice offer a valuable structure for sustaining knowledge across project boundaries. Given the siloed and temporary nature of project organizations, most of the new knowledge created gets lost as projects are dismantled (Soomro et al., 2024). Nonetheless, construction companies have acknowledged the importance of tacit knowledge and focus on capturing it through CoPs theory.

CoPs offer a valuable social structure to understand and analyze how tacit knowledge is shared and developed through ongoing interactions and shared problem solving. In fact, they create continuity across project cycles by supporting knowledge retention and routinizing new shared knowledge, therefore they are suited to the fragmented and transitional nature of construction projects (Wenger, 1998). By encouraging informal learning and collaboration across professional roles and project stages, CoPs help to preserve technical know-how and lessons learned, preventing valuable knowledge from being lost when individuals rotate (Schenkel and Teigland, 2008). Developing and sustaining CoPs in such environments requires thoughtful planning and support by acknowledging their role in relation to knowledge strategy, allocating time and space for interactions and ensuring facilitative leadership (Hizar Md Khuzaimah and Hassan, 2012). In short, CoPs are not only knowledge "containers" but living communities that help construction organizations making tacit knowledge accessible, visible and actionable ensuring long-term learning.

However implementing CoP application in construction environments presents limitations and their recognition allows for a critical and balanced analysis. The main conflicts and tensions that might arise in the study are given by emergent and informal nature of CoPs and the structured and prescriptive nature of Lean Construction tools like Pull-Planning, the author seeks to avoid these tensions by exclusively analyzing the CoP.

Although the capability of CoPs to retain and transfer knowledge from projects, participants continuously rotate through projects and fragmented organizations that get dismantled once the project is completed. This can hinder the formation and sustainability of CoPs over time, as disruptions can significantly weaken their function and learning capacity (Bresnen et al., 2003). CoPs are also sensitive to communication channels, which allow for tacit knowledge to be shared, if they are disrupted the community loses momentum and can't retain knowledge effectively, struggling in problem solving and innovation failing to support newcomers (Schenkel and Teigland, 2008). While CoP's scope in this research is to analyze tacit knowledge sharing, the author acknowledges that: tacit knowledge cannot be easily externalized and, especially, that not all of it can be translated into standardized planning practices (Schenkel and Teigland, 2008).

The challenges of applying the Communities of Practice are recognized and acknowledged by the author, however through their application it is possible to fulfill the research purpose by providing new insights in construction environments.

4 METHODS

This chapter outlines the qualitative methodologies adopted by the author to conduct the research. It details the whole research approach through the data collection, the selection of the sample, the data analysis and describes the support of AI tools and Ethics that guided the researcher.

4.1 Research Approach

This research adopts a qualitative, exploratory and descriptive approach, using an embedded case study strategy (Saunders et al., 2023). The research aims to understand how knowledge sharing enables more proactive production planning within infrastructure project teams, by drawing on an in-depth case study in Metro Project 1 and complementary interviews at Metro Project 2, onward referred to as MP1 and MP2. Both projects are ongoing and carried out by the same contractor organization and have been selected as they represent high-uncertainty and fast paced environments, that this study aims to explore.

Construction management integrates both natural and social sciences (Dainty, 2007); however, this research specifically focuses on human behaviors, social dynamics and knowledge patterns within teams, hence emphasizing on the social sciences aspects. These phenomena call for an interpretative approach based on qualitative data (Sandberg, 2005). Specifically, a qualitative case study allows for an in-depth understanding of production planning and knowledge sharing practices in real-life construction project settings (Saunders et al., 2023). Additionally, the research design follows an abductive process by iterating between empirical findings and theory, specifically the theoretical framework evolved during the study to better fit the empirical data collected (Alvesson and Kärreman, 2007).

The research purpose is to provide practical insights and instructions for effectively implementing pull-planning in MP1 project organization. Which is the primary case study and comprised multiple data collection method such as interviews, observations, documents and a final questionnaire (Saunders et al., 2023). Additionally, MP2 project has been selected for complementing and eventually contrast findings, providing a comparative perspective. Following Flyvbjerg's (2006) reccomendation for case studies selection, MP1 presents a typical scenario in metro construction, while MP2 represents a more exceptional case due to its technical and complexity. However, at MP2 only semi-structured interviews were conducted; however, they provided valuable practical insights that helped deepen the analysis of the MP1 findings.

4.2 Selecting the Sample

To ensure rich and meaningful empirical data from interviews, purposive sampling helped selecting individuals with direct experience in production planning practices (Saunders et al., 2023). The key roles were targeted based on their engagement in interdisciplinary coordination, schedule management and production planning. Specifically, the sampling focused on members of the production team, including production managers, project time planners survey managers and also environmental coordinators. The selection of participants is illustrated through the project organizational charts (Figure 1, Figure 2), provided by the contractor. Participants were selected with the involvement of the project time planner from MP1.

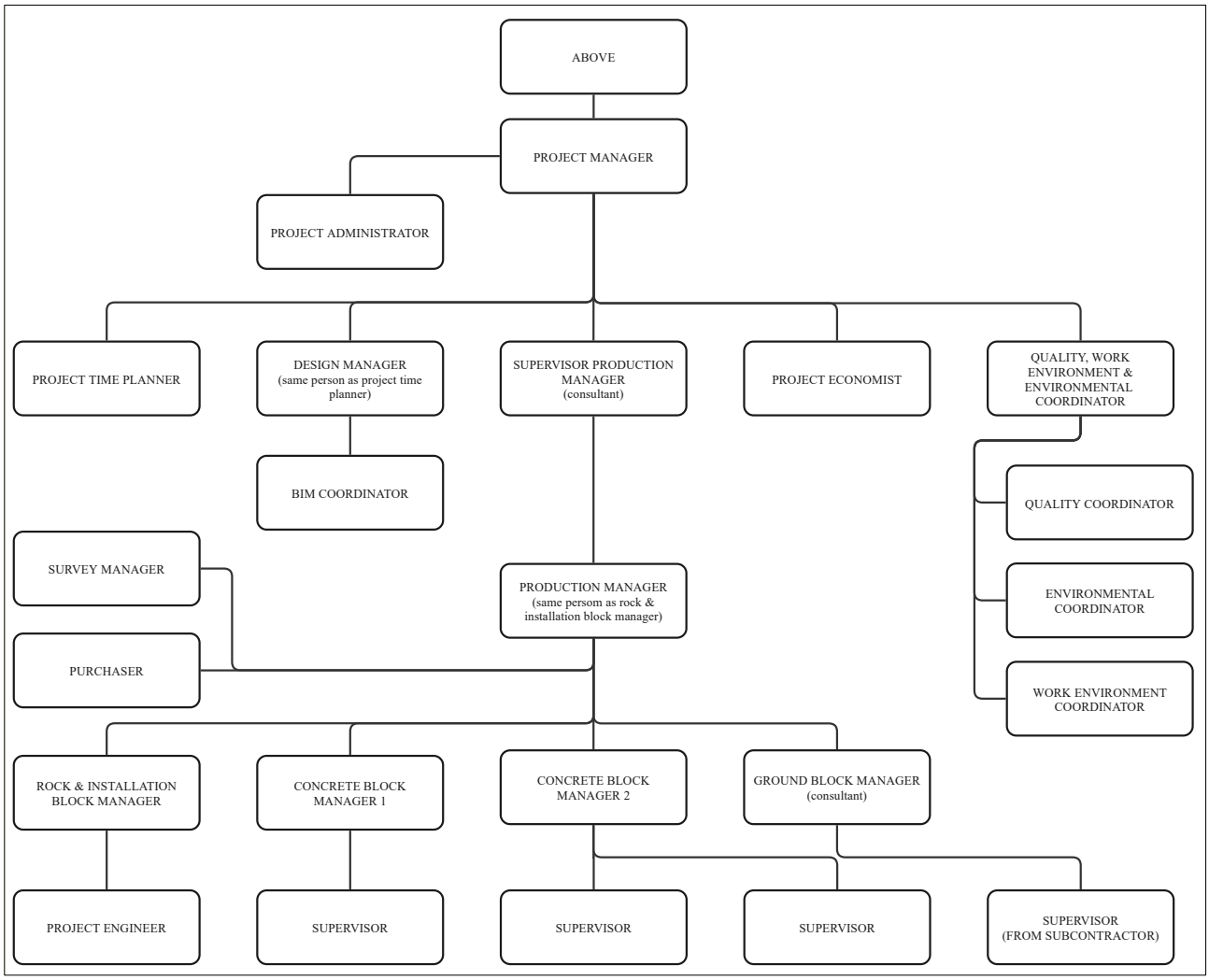

Figure 1 – MP1 Project Organizational Chart

4.3 Data Collection

To support the theoretical framing for the study, a literature review was conducted using Google Scholar as primary search engine. Theoretical scientific papers were identified by using the following keywords: Metro Tunnel Projects, Production Planning, Knowledge Sharing, Tacit Knowledge and Interdisciplinary Coordination. Empirical data collection involved multiple qualitative methods to ensure triangulation and enrich empirical materials (Saunders et al., 2023). The primary methods included semi structured interviews, non-participant observations, document analysis and a final supplementary questionnaire.

In both the projects, semi-structured interviews were conducted with the key members of the production team, including production managers, block managers, project planner and survey manager, as shown in Table 2 and Table 3. From MP1, the project time planner was not interviewed, but supported the author through numerous informal meetings and discussions. All the interviews were recorded with informed consent of the participant, and additional notes complement the audio recordings. The interview structure was based on the literature review, that allowed for gaining the theoretical overview, however the theoretical framework was not selected yet. The first structure of the interview was tested with the Survey Manager from MP1. By proceeding with

the interview, the author mastered the approach and adapted the questions to the specific roles. Particularly, to the production managers, who supervise and coordinate the block managers.

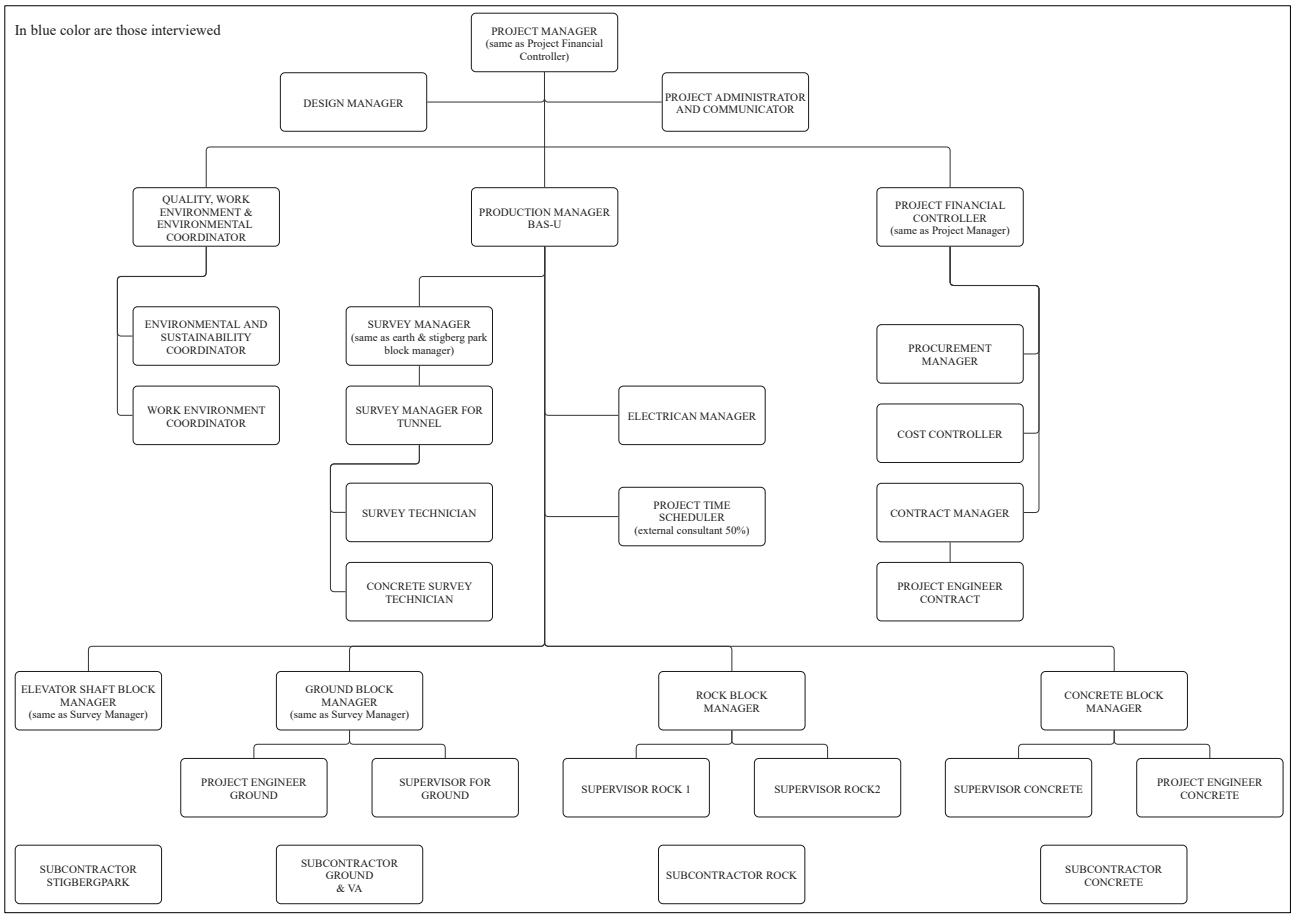

Figure 2 - MP2 Project Organizational Chart

In MP1 project, additional data were collected through non-participant observations. A total of approximately 10 hours of observations were performed in official weekly meetings, including production meetings and time scheduling meetings. The former meetings consist of reporting the weekly activities performed by each department in the organization, this provided insights into the overall project progress and priority setting. While the latter meetings allowed for deeper understanding on how interdisciplinary coordination occurs in the project. During observations field notes were systematically taken to capture the practices, interactions and discussions observed.

Furthermore, organizational charts, contracts, project specific documents, planning documents, and meeting materials were reviewed to contextualize the organizational structure and planning responsibilities. An additional workshop aiming to implement pull-planning mechanism was observed. In the subsequent workshop, the researcher played as facilitator to support the production team in applying the pull-planning method. These workshops were followed by a developed questionnaire (look at appendixes) distributed among the production team to deepen insights and perceptions into interdisciplinary planning.

Data collection was carried out between January and April 2025, covering critical periods of production planning, interdisciplinary coordination and the execution of activities within the two projects.

ROLE (abbreviation)	CONSTENT TO RECORD	DAY	LENGTH	STRUCTURE TYPE (look at appendixes)
Project Manager (PM)	yes	13.02.2025	1h, 02 min	Exploratory Meeting
Production Manager (PRM)	yes	14.03.2025	1h, 30 min	Rev 3
Survey Manager, Elevator Shaft and Ground Block Manager (GSBM)	yes	13.03.2025	1h, 16 min	Rev 2
Project Time Scheduler (PTS)	yes	02.04.2025	49 min	Rev 3
Concrete Block Manager (CBM)	yes	07.03.2025	1h, 11 min	Rev 2
Rock Block Manager (RB)	yes	21.03.2025	52 min	Rev 2

Table 2 - Interviews Conducted in MP2

ROLE (abbreviation)	CONSTENT TO RECORD	DAY	LENGTH	STRUCTURE TYPE (look at appendixes)
Supervisor Production Manager (SPM)	yes	27.03.2025	1h, 18 min	Rev 3
Production Manager, Rock & Installation Block Manager (RIBPM)	yes	26.03.2025	1h, 30 min	Rev 3
Survey Manager (SM)	yes	06.03.2025	48 min	Rev 1
Quality, Work Environment & Environmental Coordinator (QWEC)	yes	11.03.2025	58 min	Rev 1
Concrete Block Manager 1 (CBM1)	yes	12.03.2025	57 min	Rev 2
Concrete Block Manager 2 (CBM2)	yes	17.03.2025	1h, 15 min	Rev 2
Ground Block Manager (GBM)	yes	07.03.2025	1h, 11 min	Rev 2

Table 3- Interviews Conducted in MP1

4.4 Data Analysis

The collected data were analyzed through a thematic analysis, as it allows for identifying, analyzing, and reporting patterns (themes) within qualitative data. Thematic analysis provides rich and detailed account of complex practices such as knowledge sharing and production planning in construction projects (Braun and Clarke 2006).

The researcher started to familiarize with the data by carefully transcribing the interviews, reporting observation notes, and reading the documents, with the objective to achieve full immersion and understanding of data. Once all the interviews were collected and familiarized, the author inductively generated empirical subthemes. An initial coding and sorting of empirical sub-themes into themes helped the author to gain complete overview on the data, thereafter the theoretical framework was selected. Based both on the

Communities of Practice dimensions, the broader themes of production planning, interdisciplinary planning and sequencing were aligned to it. These themes were iteratively reviewed from the literature, the theoretical framework and the data. Thereafter, the findings were written thematically integrating quotations and observation to support the analysis.

In short, an abductive approach allowed for the thematic analysis through iterative development of insights by moving between empirical material and theories. As the themes emerged from the data the theoretical concepts were revised and adjusted to better capture practical implications. Meaningful and reliable findings were achieved throughout the process with reflexive practices such as personal reflections, notes and supervision discussions aiming to enhance the trustworthiness of interpretations (Saunders et al., 2023).

4.5 Use of AI Tools

In line with current research integrity standards, the use of AI tools during the thesis development is disclosed. AI tools, such as ChatGPT was used in a limited capacity to support the writing process. Specifically, to brainstorm section structures, refine phrasing for improved readability, and summarize preliminary reflections into coherent drafts. No data analysis, empirical interpretation, or theoretical development was conducted through AI tools. All critical thinking, data interpretation, thematic analysis, and final text editing were conducted independently by the researcher, in accordance with ethical research guidelines (ALLEA, 2023).

4.6 Ethical Considerations

This research follows the highest ethical standards, throughout all of its phases, outlined by Swedish Ethical Review Authority Guidelines (Görman, 2023) and European Code of Conduct for Research Integrity (ALLEA - All European Academies, 2023). Integrity, transparency, and rigor were maintained throughout all research phases. All participants were fully informed about the purpose, methods, and potential implications of the study. Interviews were recorded only with explicit permission; otherwise, detailed notes were taken. Participant anonymity and data confidentiality were guaranteed at all stages, with data management strictly adhering to GDPR requirements. Validity of data collected via interviews have been supported, when possible, by the application of the following three principles: communicative validity, pragmatic validity and transgressive validity. Participants' dignity, autonomy, and rights were respected throughout the research process. Data ownership aligns with the FAIR principles (Findable, Accessible, Interoperable, and Reusable), and anonymized data may be shared responsibly to contribute to open science initiatives. Any potential ethical issues arising during the research were addressed promptly and transparently, with a commitment to promoting fairness, accountability, and societal contribution. The research aims to contribute positively to academic and societal knowledge.

5 FINDINGS

This chapter presents the findings gathered from fieldwork at the MP1 and MP2 project organization. The findings are divided by project and structured based on three dimensions around which Communities of Practice are defined: domain as the shared concern that provides identity, community that shapes how mutual engagement is established and practice that represents repertoire of common routines and practices.

5.1 MP1 Project

MP1 is part of a major transportation hub that encompasses a new bus terminal and the new train station of regional and commuter trains and will become operative from 2027. In January 2024, the current contractor officially took over the work after the client terminated the contract with the previous one and the new *construction cost plus fee contract* was signed in autumn 2023. Even though, the new contract's scope comprehended the construction of two elevator shafts, a ticket hall and the underground station building, few refinements were needed and directives from the client side were lacking, affecting the initial phases. Moreover, as the new extension must be operative by the beginning of year 2027, time pressure is high. Particularly, the previous contractor project timeline was on the 31st of January 2025, however, due to the cancellation with the previous contractor, it has been shifted by autumn 2025, when the technical railway works will start.

The organization is led by Project Manager and includes multiple departments, with the production team at its core (Figure 1). This team, coordinated by the Production Manager and Supervisor Production Manager, is responsible for planning, execution, and control. A dedicated time planner oversees the master schedule. The production team is divided into three blocks by discipline: rock and installation works, concrete works, and ground works. Each block manages its own team and scope: from rock reinforcements and injections, to scaffolding and concrete casting, to drainage and mucking. Although the technical work may appear standard, the Project Manager noted informally: "It's easy, just simple concrete works", yet emphasized the complexity of interdisciplinary coordination in the confined tunnel environment.

5.1.1 Domain: Production Planning Through Sequencing

Production Planning is the shared concern that unites team members within MP1 project's production team. It happens through sequencing practices that aim to find the most appropriate order of activities under limited time and with resources constraints. The routines are not merely tasks, as they consist of team efforts around which the team responsibilities evolve. "Because it's a sequence you need to recognize" remarked CBM2 by acknowledging that sequencing requires overview, judgement and collaborative reflection.

Production planning unfolds in sequencing practices, which entails team efforts, where block managers, time planner and production manager engage in collaborative formal and informal meetings, where priorities are negotiated and activities aligned. An evident example comes from the dedicated workshop attempted to implement a pull-planning method to accelerate sequencing decisions. Although the method was not fully

mastered, the intense team engagement and joint problem-solving during the session reflected sequencing's centrality to the community's shared work.

Production planning tasks are perceived as both technical and psychological. While they define the work execution, they develop emotional investment, accountability and pride among team members. As RIBPM argued "the more you plan, the more you demonstrate the importance of a task to a colleague", while SPM explained "if you plan yourself, you start thinking about things that you need for your work. And then you feel responsible". The team cohesiveness and efforts must have the right space and time to effectively engage in shared efforts. Accordingly, GBM emphasized the need of time and calm for doing proper planning: "There should always be time for proper preparation before planning, without stress, to ensure everything is thought through". Also SPM emphasized: *"You need to plan, plan, plan, plan, plan and then start".*

The coherence and adhesion of the production team is further supported by two delegated production managers, that empower and motivate the team to interact collectively toward aligned goals. "The project is not finished until everyone is finished" said RIBPM highlighting the importance of collective progress over individual success. Similarly, SPM argued: "If more people strive for the same goal, it's easier, people understand each other. Then everybody and every discipline is involved". Beyond operational alignment, both managers actively empower the team, as SPM recognized: "people should feel good and happy and respect each other. […] No stress. Go home. Be safe. It's not just technical things". They both reinforce an environment of respect, encouragement and emotional balance, underscoring the emotional task related feelings. RIBPM echoed: "Just be happy and positive, so people may be happy. We see that, it's not just going to work, you have to be happy and feel good.". These cultural elements highlight that production planning is both a functional and a socially meaningful process that shapes team motivation and identity.

However, achieving appropriate sequencing is not always possible. Precisely, SPM stated: "we fail in planning, that's the biggest waste". Several team members noted that time pressure and lack of overview often hinder such preparation works, which lead to a reactive approach. In fact, GBM stated: "We had a couple of storms that happened in this project. Because we didn't get this clear overview. When you don't have a clear overview, you cannot prioritize the work". Moreover, time pressure and intense level limit detailed planning, and such cases planning is replaced by reactive control practices, as GBM noted: "And I have been continuously monitoring and controlling the work. Since the beginning, production has been running at this compacted, intense level without a break. Control, I would say, is the key. Through proper control, you can prevent many problems."

In conclusion, production planning and, more precisely, the effort of sequencing is the domain of MP1 project's community of practice. It is the shared concern that provides identity and focus by giving coherence to the team's activities. While effective planning allows for emotional ownership, accountability and pride, the reality of production constraints often lead to reactive control. Nonetheless, the collective effort to continuously define and adjust the sequencing binds the team together.

5.1.2 Community: Interdisciplinary Coordination Through Dialogues

Interdisciplinary coordination represents the community interactions and mutual engagement that occur within the production planning team, binding the team members together into a cohesive social entity. Construction activities are tightly sequenced in the tunnel, and multiple teams often work in overlapping areas, therefore MP1's production team members engage in interdisciplinary coordination to define appropriate sequencing, where they align their schedules for preventing inefficiencies. Accordingly, SPM remarked: "If everybody is in the same place, then it's often a problem". Hence, block managers must engage in discussions for providing the right inputs to define sequencing, as RIBPM remarked: "The most important thing, it's the block managers talking to each other".

Discussions and **dialogues** occur formally in meetings or informally. Once a week, the team participate in the time planning meeting where the traffic within the tunnel is discussed and decided. However, detailed coordination occurs in informal meetings, as CBM1 described: "If there's some area that I need to cooperate with the ground workers, I go to S. (the GBM) and we sit together in the office or S. comes to me". This highlight decentralized interdisciplinary coordination within the production themes.

Effective interdisciplinary coordination depends on the level of detail in planning discussions. Proper detailed dialogues enhance transparency and awareness between block managers, who should contribute by providing their inputs in the sequencing. As GBM noted in the questionnaire: "The process will be smoother as everyone is aware of different steps and their influence on other activities. […] the inputs from other disciplines were needed for finding an effective solution." Hence, discussions are essential for promoting mutual understanding between individuals, leading to a proper scheduling process. Moreover, according to RIBPM and SPM, proper level of detail is ensured if the respondents are interested and curious about each other needs and works, highlighting the interdisciplinary coordination dependency on individual initiative.

The required level of detail depends on the participants and the complexity of the task. When teams are already familiar with each other's scope, dialogues have less detailed level. As observed: "colleagues did not go into a very detailed level of their work. In this case it was fully okay, because everybody had a good understanding of each other's activities. With other disciplines being part of the critical path, electricity, installation, welding, for example, it would have been necessary to encourage everybody to present as much as possible of single activities". However, there has not always been such understanding between disciplines. Group planning meeting help achieving proper level of detail for ensuring full understanding. Nonetheless, beforehand preparation plays a key role, if block managers don't perform sufficient detailed planning beforehand, meetings become frustrating. GBM explained that delays can occur if linked activities aren't considered in advance. This was also evident when PTP occasionally missed important dependencies, such as access to work areas. As a result, detailed individual planning is a prerequisite for productive group discussions.

Undoubtedly the level of detail depends on the awareness of people and complexity of the tasks, as PTP emphasized: "The higher the complexity, the more time and rounds would have been required. As well as a different level of summarize and visualization." Additionally, visualization tools, such as 3D models, help

clarify complex plans ensuring full shared understanding. A specific visualization method is the 3D Bim model which is fully understand and extensively used by the whole team. As CBM1 highlighted: “You can just open a model of the station and visualize it together, it makes coordination much easier.” However, 3D models are different for each block manage, resulting in decentralized and fragmented visualization.

In summary, interdisciplinary coordination represents the community’s core dimension of mutual engagement within the MP1’s production team. It occurs through repeated interactions, both formal interdisciplinary planning meetings and informal office discussions. These interactions are not only procedural, but they are the everyday practices that bind individuals into a functioning community. Through shared dialogue, curiosity about other’s tasks and joint problem-solving, team members build shared understanding and a common identity. Finally, interdisciplinary coordination is the social glue that allows the community to exist and evolve according to the project uncertainty demands.

5.1.3 Practice: The Shared Routines for Sequencing

Sequencing reflects the practice dimension of MP1’s production team. It is the repertoire of shared practices and routines, which are detailed planning, scheduling, planning the logistic and prioritizing, all supported by visual communication, leadership facilitation, formal procedures and documentation and personal experience.

5.1.3.1 Detailed Planning

Detailed planning forms the foundation of production planning. By performing it, block managers develop a sense of emotional ownership and pride in the project. RIBPM mentioned: “Most of the planning, the block chef does in details”, precisely each block manager is responsible for individually preparing their own work scope, while ensuring alignment with the others. Detailed planning includes a set of tasks, such as identifying interdependencies, estimating durations, managing material, resources and equipment, and preparing safety and quality documentation. However, detailed planning depends on the schedule, that has already outlined a draft of the project sequence, as CBM2 mentioned: “Our internal coordination is based on the main schedule. But I make my own schedule based on it, and I share with my support group and subcontractor”. Moreover, detailed planning entails providing the decisions and information to the subcontractors.

5.1.3.2 Scheduling

Scheduling is at the base for detailed planning. Planning is structured on two core schedules: the long-term production schedule defines contractual milestones, and the rolling schedule, that is biweekly updated, guides day-to-day work. However, these schedules must remain dynamic and interconnected. As stated in the ProjektPlan, “Each activity must have a preceding and a following activity or milestone.” However, not all team members find the main schedule accessible, as SPM observed: “Some people, you think they can read it but they can't read it: it's like Greek for them.” Consequently, block managers often supplement it with simplified, personalized planning tools, leading to decentralization and fragmentation. Accordingly, CBM2 described: “I compare with our main schedule, but I make my own schedule, and I share with my support group.”

5.1.3.3 Prioritizing

Prioritization is critical for ensuring smooth sequencing. Given the overlapping nature of tasks in the tunnel narrow spaces, block managers must identify the urgency of activities and evaluate potential clashes. “You have to take a decision. Who goes first? Is it the ground workers, or the concrete, or rock teams?” (SPM), this decision-making process often requires balancing strategic goals with site realities and constraints, by evaluating each activities urgency and criticality. CBM2 furtherly argued: “That's why there exists something like the buffer time… if something is going to happen — in example, I don’t have this material, or excavator is broken, or something — but you need some buffer time. And if I give him half a week of buffer, then I know if something switches at his work, I'm still on track.” Buffer times are sometimes introduced to manage interdependencies between activities, but often there’s little margin. CBM2 reflected, “If I have a deadline, then you decrease those buffer time. It’s nice to have it, but sometimes you cannot get it.” However, waiting is time and cost inefficient and it leading to delays if not well planned.

5.1.3.4 Logistic Planning

Logistics planning is among the most demanding aspects of sequencing, particularly within tunnel environments. This challenge is recognized throughout all the organization, in fact, managers must coordinate access, space, and material deliveries to avoid physical overlaps and safety risks. Accordingly, RIBPM emphasized this difficulty: “The hardest thing to do in this project is to plan logistic. The tunnel is narrow and we have a lot of disciplines.” When logistics are not properly managed, over than productivity also safety is compromised, as QWEC explained: “If we don’t have any escape ways and there are 50 people working in one section but only chambers for 30, they’re 20 too many”, and the works can be stopped. Therefore, some methods must be followed for managing this complexity.

Buffer Times and **Stand-by-Jobs** are introduced to handle this logistic complexity. CBM2 suggested that buffer time provides good help, however as discussed earlier, gaining additional time is often not possible. As an alternative, SPM introduced the concept of stand-by tasks: “I called it *Beredskapsjobb*, when you can't work on the critical line because there will be some excavation or something, these people need somewhere to go always.” These contingency tasks act as temporary buffers between different working teams, avoiding time waste and maintaining productivity.

5.1.3.5 Support Structures: Visual Communication, Leadership and Formalization

Support is needed by the block managers when dealing with such complex tasks. Facilitative leadership, visual communication tools, formal practices and personal experience of block managers provide support. **Visual Communication** tools play a vital role, and include 3D BIM models, annotated screenshots, PDF drawings, and presentations. These visuals tools help bridge disciplines and experience levels gaps promoting mutual understanding. CBM1 noted, “You can just open a model of the station and visualize it together, it makes coordination much easier.” GBM described the need to make content accessible throughout the team: “I try to make simple presentations that they can take with them, not just something modern that they see once and forget.” However, not everyone is equally comfortable with digital tools. As GBM observed, “Most

supervisors don't have a university degree… it's really hard for them to use these models." Although, these visual tools support mutual understanding, particularly the 3D model provides good overview, these outlined issues fragment their use leading to mismatch and misunderstanding.

Leadership also plays a crucial enabling role in sequencing practices. Rather than imposing rigid plans, production managers support block managers and ensure alignment by giving responsibilities and establishing shared goals through open communication. Accordingly, SPM explained: "I let people make their own decisions. Otherwise, they're just following a paper." This leadership style reinforces planning as a collaborative process and also cultivates a positive team environment. Indeed, RIBPM reflected, "If I'm happy, maybe other people see that I'm happy. You have to be bounded. Everybody is… you get a big team. I think that's important." However, as the team lacked directives from the client, the style of leadership in MP1 is a *searching leadership* one, where the production managers, while empowering, were lacking of clear directions.

Formalization unfolds into structured that support the planning process with tools, such as arbetsberedning and control plans, that are mandatory before initiating tasks, ensuring safety, quality, and environmental protocols are addressed. As QWEC emphasized, "I am responsible to sign the arbetsberedning… if it's not in order, we are not allowed to start." Formalized procedures are intended to reduce fragmentation, as CBM1 noted: "Here we don't improvise so much because everything must be documented and if there is something we have to change we have to always talk with our client".

5.1.3.6 Tacit Knowledge Balance & Learning

Sequencing practices are shaped by a dual structure: formal procedures offer guidance and reliability, while tacit knowledge – grounded in personal experience, judgement and intuition – drives daily decision making. Much of the sequencing practices are conducted through personalized routines that are rooted in **experience**. Most of the team members have between 10 and 25 years of fieldwork and rely on practical **judgement** rather than formal calculations to estimate durations, assess clashes, and plan sequences. Accordingly, CBM2 emphasized: "Right now we are working based on our experience". CBM2 similarly noted: "Time estimation is something you learn by doing". While CBM2 illustrated how **intuition** acts when sequencing interdependent tasks: "Those two walls can be executed in parallel, because there's no collision… so you assume it takes three or four weeks."

Tacit knowledge becomes particularly important when handling uncertainties related to interdependent tasks and complex works. However, this reliance on intuition leads to different interpretations among members, contributing to practices fragmentation and inconsistencies, as GBM with some frustration noted: "I think that… they missed some parts through the planning. […] So I think that my time planning is different than a couple of my colleagues." Formalized procedures sometimes are perceived as additional administrative and bureaucratic layers, especially when not fully connected to detailed planning, however, they are generally recognized as necessary to ensure transparency, structure, and accountability. Accordingly, CBM1 noted: "Here we don't improvise so much because everything must be documented and if there is something we have to change we have to always talk with our client".

Learning reflects how tacit knowledge is shared and captured in the organization. Within the team onboarding exists, it is relatively lightweight and relies heavily on informal mentoring, learning by doing and personal experience. CBM2 recalled that most project-specific learning came from performing tasks directly, and by applying his developed experience. Similarly, CBM1 learned by observing a senior supervisor and gradually taking on more responsibility. SPM shortly described: "It's not like reading a book and then building. You plan, try it, see what worked—and adjust the next time." In short, production knowledge in MP1 is predominantly tacit, built through accumulated experience and refined on the job. While formal tools and procedures support consistency, learning and adaptation occur through practice, mentoring, and reflection. Balancing structure with flexibility is essential to both individual learning and project-wide coordination.

In summary, sequencing is not a predefined procedure, but an evolving practice shaped by interaction, iteration, and interdependence. Detailed planning, scheduling, prioritizing, and managing logistics are performed through a combination of structured tools and informal adaptations. These efforts are supported by visualization, leadership, formalization, and practitioners' experience. Together, all these aspects constitute the shared practice dimension of MP1 Production team's Community of Practice.

5.1.4 Pull-Planning Implementation: Challenges and Lessons Learned

A pull-planning workshop was organized to coordinate the construction of two walls on the critical path, with the aim of introducing the team to the pull-planning approach. The session was facilitated by the Project Time Planner (PTP) and a manager of the company. While the intention was to collaboratively define the work sequence, the discussions quickly became unstructured and difficult to follow, particularly for external observers. Despite this, a workable plan was eventually developed and summarized by the PTP, which allowed the client representative to approve its execution.

The experience highlighted several limitations in the team's readiness to adopt pull-planning. Although team members supported by facilitators attempted to applying pull planning, many block managers had not completed their detailed individual planning beforehand, and some were absent, resulting in lack of clarity and coherence. According to RPM, preparation was a key issue: "You have to come to the meetings prepared […] we have to practice it, that's important." SPM agreed and further stated that it should be clear which methodology is applied to find solutions during meetings. Despite these issues, the team showed openness to learning and maintained a shared willingness to solve problems together. Additionally, the workshop illuminated the following stepwise approach, essential for interdisciplinary planning:

- Establish awareness of issues and provide guidelines and baseline.
- Detailed individual planning by Block Managers.
- Group refinement of the plan.
- Present the refined plan.
- Time for individual reflection.
- Joint review for stress-test and resolve conflicts emerged.
- Summarize and present updated plan.

Accordingly to the plan, first, block managers must be given time to complete their individual planning to develop a full awareness and clear understanding of scope, constraints, needs and interdependencies. This enables a shared baseline from which the team can collectively refine the plan, which must be presented with all the conditions and requirements prepared. The second step involves a joint review with detailed discussions about the sequencing to stress-test assumptions and resolve conflicts. Finally, the updated plan should be clearly summarized and agreed upon by all parties. Moreover, additional time may be needed between steps for reflection and adjustment. As interdisciplinary planning manages sequencing and logistic through group planning meetings - that help develop and share new knowledge about the project, it is not immediate, and reflection time must be given to members. In fact, in MP1 tunnel environment, coordinating logistics adds a layer of complexity to sequencing, requiring even more clarity and shared understanding among block managers.

In this case pull planning method was not implemented because of many reasons. The team did not master the mechanism before, some members were missing or unprepared and there was limited time to learn the method. However, the experience revealed important preconditions for its adoption: clear expectations, individual disciplinary preparation, and repeated practice. As RIBPM added: "You need to have a lot of meetings so that everybody will understand how the process goes. We have to practice it, that's important. […] and you need to have the time to learn pull-planning."

In summary, introducing pull-planning requires both technical preparation and cultural adjustment. Block managers must not only acknowledge the method as a coordination tool but also commit to early and structured planning, by starting to perform their individual detailed planning. Nevertheless, the team should be given time to learn and master the mechanism by practicing it before the beginning of the execution phase. In this case, the workshop remained a one-off exercise rather than a recurring planning method embedded in project routines.

5.1.5 Summary: MP1 Production Team's Community of Practice

MP1 Production Team's community of practice is defined along its three dimensions: production planning constitutes the domain, interdisciplinary coordination represents the community interaction and sequencing forms the main shared practice.

Sequencing is the team shared concern that defines the team's purpose, coordination routines, and collective identity. Through the practices of detailed planning, scheduling, prioritization, and logistical preparation, team members engage in daily interactions supported by tacit knowledge, visual tools, and formal structures. Planning practices develop ownership, motivation, and professional pride within team members, however their effectiveness highly depends on time and overview availability and a clear sequencing strategy.

Interdisciplinary coordination occurs mostly through informal interactions, where mutual awareness and curiosity enable alignment across disciplines. While formal meetings are also established for developing a final sequence of work's activities, they lack clear structure and directives. When planning time is insufficient reactive control measures replace proactive preparation, leading to fragmentation and inefficiencies.

Learning happens through learning by doing, mentoring, and shared reflection. These mechanisms are essential for practitioners to adapting to project dynamics, although individual approaches still vary. The pull-planning workshop further revealed that successful implementation of new methodologies requires early preparation, consistent practice, and clear expectations.

Overall, as represented in Table 4, production planning in MP1 production team is both a functional and emotional process, that is shaped by experience, social cohesion, and shared responsibility. However, its full potential is only achieved if the team is given time and support to plan, coordinate, and learn together.

Dimension from Wenger (1998)	Empirical Findings	Main Theme
Domain	Sequencing practices guide planning routines under time/resource constraints and bind the team around shared goals and accountability. Production planning occurs through sequencing as it is the core shared concern.	Production Planning
Community	With dialogues and discussions both in formal and informal meetings block managers align tasks, discuss interdependencies, and share mutual responsibility.	Interdisciplinary Coordination
Practice	Detailed Planning, Scheduling, Prioritizing, and Managing Logistics - supported by visual tools, searching leadership facilitation, formal procedures and personal experience – define sequencing.	Sequencing

Table 4- Summary of MP1 Production Team's Community of Practice

5.2 MP2 Project

MP2 Project is part of the Stockholm Blue Line extension and its construction involves complex engineering, starting from the excavation of ordinary and the service tunnels, and the construction of a challenging elevator shaft (Region Stockholm, n.d.). This project presents different set-up, delivery model and preconditions to MP1. In May 2021, a performance contract, based on the AB04 Swedish Standard which aligns with a Design-Bid-Build approach, was signed. Accordingly, the client is responsible for the main design, while the contractor executes the construction work. Specifically, the contractor is responsible for tunnel excavation, as well as the technical design and execution of the concrete works for the underground station and elevator shaft.

As the contract setup and procurement stages were different in the two projects, the findings also vary. For MP2 the contractor has more control over costs and risks, while in MP1 the contractor is more dependent on the client choices. Therefore, production planning, interdisciplinary coordination and sequencing practices slightly vary between projects, however, the findings were used to synthetize and learn lessons across projects, acknowledging and accounting for the substantial differences.

The size and complexity of the project required a large organization capable of managing its various components. In the organizational structure (Figure 2) the departments and positions are organized under the Project Manager. As in the MP1 project, this study focuses on the production team and the time scheduler. In the MP2 organization, the time scheduler is an external consultant working 50% on the project. The production team is divided into four blocks or disciplines, each responsible for a specific scope: tunnel excavation, concrete works, ground works, and the elevator shaft works. Similar to the MP1 project, each block is represented by a block production manager and coordinated by the overall production manager.

5.2.1 Domain: Production Planning through Sequencing

Production planning is the main shared concern around which all members of MP2 Project Production Team's orient and shape their practices. It fundamentally consists of sequencing and relies on a solid structure that clearly identifies the project's practices, responsibilities and goals. However, it does not only consists of structured practices that determine the right order, timing, and spatial coordination of construction activities across disciplines. It also forms the basis for how responsibilities are assigned and goals are pursued.

In MP2, Block managers hold full responsibility for planning within their scope and are empowered to adjust based on evolving site conditions. The production manager supports overall coordination and team cohesion. As PM explained, "The block managers have the mandate to do changes needed to a certain extent […] you can't really do the planning work without the ability to actually manage it as well." This emphasis on planning reflects a broader logic that shapes how the team works, as it serves both as a technical and social function.

Production planning enables temporal and spatial alignment between activities, preventing interferences and clashes, establishing and sustaining a shared strategy. For instance, the elevator shaft, located at the center of the tunnel, must be prioritized to avoid isolating the north section: "Because the elevator shaft is in the middle of the south and north of our tunnel. If we do any works thee, the whole system to the north is locked

down" (PRM). Managing access, avoiding clashes, and adapting to unexpected events are central concern, making of production planning a reflective and strategic domain, that provides a foundation for learning and supports. Without its practices, production planning would risk becoming a static list of tasks rather than a dynamic and situated management process.

The centrality of this concern is also reflected in leadership practices. As the PM remarked: "I want everyone here to know, and it should be very clear, what our targets are and that people feel that they have the responsibilities and the means to do it." Accordingly, production planning reinforces emotional ownership and accountability across the production team. Its practical value lies in maintaining control over the project while remaining flexible and responsive to deviations, as GSBM explained: "This planning is important for me to keep control over what is sent to the site […] so I really know what's ongoing and what we need. Of course, things deviate from the plan, unexpected things happen and you need to adjust".

In short, production planning routines is not only a set of practice through which sequencing takes place, but it is the domain that unites the team's attention and decisions. Its structures enable interdisciplinary coordination by defining responsibilities, leadership approach and supporting collective learning. Through sequencing the production team builds up its shared domain of practice, allowing for coherence and collaboration among the team, anchoring member's roles in a common purpose.

5.2.2 Community: Interdisciplinary Coordination through Dialogues

Interdisciplinary coordination in MP2 represents the community dimension. It is the space where mutual engagement happens, knowledge is shared and team members are socially and practically connected. This ongoing coordination is essential to align work across disciplines, prevent clashes, and ensure the project's progress, especially in the complex underground environment where spatial constraints and task interdependencies are constant challenges. Moreover, it is non-negotiable due to the project's uniqueness and technical demands. Block managers must be constantly aware of how their activities depend on and affect others. Accordingly, PRM argued that single disciplines, such as concrete works, cannot "live their own life", as execution is shaped by physical and temporal interdependencies. GSBM illustrated this: "If we are blasting at the same time of concrete works we need to communicate, because these vibrations are not good for the concrete." Similarly, RBM pointed out that blasting and loading operations require the exclusion of other teams from certain tunnel sections for avoiding clashes and for safety reasons.

These dependencies directly shape how activities are sequenced and how coordination is managed. Undoubtedly, the team must engage in extensive interdisciplinary interactions and shorter coordination meetings to ensure team alignment. Accordingly, PRM argued: "We put in shorter meetings every week just to make sure that we go into the direction of the goal. So that we make sure that the goal line is set and that we are going to reach it." These interactions help the team continuously revisit shared targets and detect potential conflicts early. They occur through dialogues in structure official meetings and informal everyday dialogues, and bind member together, establishing the common concern of sequencing.

Dialogues and **discussions** are the core mechanism through which team members coordinate and develop accountability into the project, as PRM emphasized: “They need to talk with each other a lot. They need to discuss almost every day […] They have a mutual responsibility in it.” Planning and coordination dialogues and discussions take place in both formal and informal meetings, intentionally structured to maintain balance between short-term and long-term coordination.

Formal coordination meetings are held to review upcoming activities, set shared goals and establish mutual responsibility, while informal conversations are used to solve practical problems and make rapid adjustments. As GSBM explained: “If you just want to deliver information, then maybe it’s better to catch up in the conference room. But if you want to figure out how should we do something, then it might be better to speak down in the kitchen.” PRM highlighted the importance of setting targets and noted the difference between formal planning meetings and informal ones: “It’s very important to me that we start the week agreeing on the targets”. The PRM plays as facilitator in these settings, guiding conversations with open-ended questions rather than directing actions: “I ask open questions. You can't answer with no or yes. […] I try to lead in a very friendly way, let everyone talk, bring up the latest issues, and ask what kind of help they need.” These leadership practices support team reflection and alignment, encouraging individuals to identify and address challenges collaboratively. GSBM added: “If they are asking the right questions… I know they understand. If they don’t ask anything, I doubt.” In this sense, curiosity and open inquiry are signals of engagement and comprehension, while silence can indicate a lack of clarity, however, leadership help ensure mutual understanding between individuals.

To avoid misalignments in dialogues block managers must match the level of detail required to each task. The level of detail depends on the complexity of tasks and their impact on the whole project, as PTS explained: “For the elevator shaft, because it’s so critical, we go into one-day activities. For the master plan, five-day activities are enough to follow up. If it’s too long, it’s not good”. PRM noted that highly detailed meetings are held weekly to plan the elevator shaft specifically, reflecting its role on the critical path: “We have a weekly meeting where we plan the works in the elevator shaft in detail […] not every discussion goes that deep, it depends on the scope.”

In summary, interdisciplinary coordination is not only a practical necessity but how the team is bound together. Through structured meetings, informal dialogues, shared problem solving and open leadership, team members remain mutually engaged and collectively responsible for progress. These continuous interactions form the community dimension of their practice, sustaining collaboration, alignment and trust across disciplines.

5.2.3 Practice: The Shared Routines of Sequencing

Sequencing reflects the practice dimension of MP2’s production team. It represents the repertoire of shared routines and tools that structure how planning, coordination, and adjustments are handled in day-to-day work. These include the time schedule, follow-up processes, sequencing logic, and logistic planning. They are supported by visual communication, structured routines, active leadership, and personal experience. This

shared practice enables the team to adapt to uncertainty, while maintaining alignment and control, and to develop ownership into the practices and a sense of pride into the project.

5.2.3.1 The Schedule Follow-up Mechanism

The **schedule follow-up mechanism** anchors all planning and coordination processes. Even though working part-time, PTS plays a crucial role given the project complexities and uncertainties. The schedule is maintained through long and continuous procedures, and its purpose is to provide a reliable structure for execution and coordination, as PM emphasized: "since it is such a huge schedule, our scheduler has several thousand roles in it". The schedule breaks down the tunnel into phases, separating planning and execution periods across disciplines, identifies the critical path, particularly the activities in the elevator shaft, and provides each block managers with the outlines to develop their own detailed plans.

The follow up process is relatively simple but essential. PTS weekly meets individually with the block managers, who report on progress and eventual changes. Based on this updated, the schedule is adjusted and new outlines are provided. As the PTS described: "And then it I put it in the big-time schedule and we look together at the consequences". Sometimes, rough completion percentages are used to keep track of progress and encourage discussion about activities impact. After the individual meetings, PTS follows up with PM, who provide a full project overview.

By **prioritizing** the most critical activities, usually related to the elevator shaft, the PTS establishes the first order of activities across scopes. The PTS uses a detailed Gantt chart to visualize and communicate these priorities, helping the team detect potential delays and coordinate activities. As the PTS explained, "Everything that's going on in the shaft is the critical work in the project, so everything that happens there will have a direct consequence on the end date." These centralized priorities form the baseline from which more detailed, local planning is developed.

5.2.3.2 Individual Detailed Planning

Detailed planning is exclusively performed by the block managers. Who, building on the PTS's outline, manage resource allocation, subcontractor coordination, material planning, and documentation related to safety and quality. This planning is adapted to the nature of each scope, for example, rock excavation involves repeated and resource-intensive tasks, while concrete work may focus more on sequence coordination. Additionally, block managers adjust plans in response to shifting conditions and ensure their teams have the information and tools needed for effective execution. However, this level of planning relies on professional experience and interpretation.

Block managers additionally need to set daily and weekly **priorities** within their scope. While some activities follow rigid sequences, many are flexible and must be adjusted based on material deliveries, progress by other teams, or spatial availability. This decentralized prioritization supports responsiveness and adaptability, allowing managers to maintain momentum even when plans change. It also reinforces their autonomy and accountability within the overall planning system.

5.2.3.3 Managing Logistic

Managing logistic is a critical part of the team's shared practice, particularly in MP2's underground conditions where space is extremely limited. There is only one transport tunnel, and multiple teams must operate in overlapping zones. To prevent physical and temporal clashes, block managers divide underground workspaces by discipline and coordinate closely with one another. As PRM described, "We only have one transport tunnel… and there are many collisions between concrete and groundworks. So that's what we discuss in meetings." PM added, "We divided the areas below ground as much as possible, so you don't stand on the same spot working with concrete, earthworks and rock at the same time."

The **APD** supports logistics coordination. It is a 3D visual presentation of spatial and temporal activity distribution that allows teams to anticipate constraints and plan access effectively. As PTS noted, "The whole work is connected to a specific physical place… some activities they can work simultaneously, but some — like drain mats — require exclusive access." As the project advances and more teams enter the same zones, logistics becomes increasingly complex. RBM noted: "It's a tricky challenge. The further the project goes, the more people get involved in the same place." Under these conditions, block managers must remain flexible and agile to make daily adjustments, using shared tools and routines to ensure safety and continuity.

5.2.3.4 Support Structures: Leadership, Visual Communication and Formalization

Leadership, visual communication, formal delegation, and tacit knowledge all play a critical role in shaping and sustaining the shared planning practices of the MP2 production team. Empowering **leadership** facilitates, guides conversations and ensures collective reflection. As PRM emphasized, "I ask open questions… I try to lead in a very friendly way, let everyone talk, bring up the latest issues, and ask what kind of help they need." A key leadership strategy is guiding the dialogues in a way that promotes ownership and problem-solving, as PRM further described, "I make sure they talk to each other. I listen to all the facts, ask questions… What do we win? What do we lose? Then we lead our way. Like a snake." This approach encourages mutual engagement and allows interdependencies to naturally emerge, enabling collaboration among the team.

Visual communication tools support mutual understanding. Tools like the APD model, BIM animations, and 2D site plans help make complex information understandable across disciplines. As PM noted, "We have visual planning, which we update every week… Visualization of where we are." Moreover, these visuals tools beside aligning understanding they are essential for helping managers adapt plans according to site-conditions. **Formal procedures** and **delegation structures** define responsibilities and support consistency. Block managers are formally mandated to lead planning within their scopes, while the time scheduler and production managers provide support for alignment, coordination, and oversight.

5.2.3.5 Tacit Knowledge Balance and Learning

In MP2, production planning is based on a balance between tacit knowledge—including experience, intuition, and personal judgment—and formal tools and procedures. Most members have over 15 years of experience, with some having started on construction sites at the age of 15. As a result, block managers approach planning

differently depending on their background and expertise. Accordingly, PTS highlighted: "The schedule is based on the managers' estimation. We look at if we've done similar activities in the past. The main thing is that the time plan is realistic and reflects reality." This reliance becomes especially important in high-uncertainty tasks, such as the elevator shaft.

Accordingly**, personal experience** and **intuition** are the fundament for managing uncertain and complex conditions, ensuring flexibility and responsiveness. As GSBM explained, "There are no similar jobs… If you're not experienced, you need to ask someone who's done this job before." However, planning based on individual experience may lead to diverging interpretations or inconsistencies, especially in high-pressure phases. This makes the role of shared structures and mutual awareness critical for alignment. Moreover, in MP2, there is high integration of formal and informal procedures improving the team's ability to execute under uncertainty while maintaining shared objectives. Clear delegation structure and established interaction procedures, such as the schedule follow-up mechanism, define the boundaries within members can plan based on their experience, judgement and intuition. This structure definition allows team members to be aware of theirs and others mandate, ensuring consistence of interpretations. As PM stated, "We need a system where you know your mandate, what you can do, what you're responsible for, and when to ask. And have the main frameworks set up early."

Learning identifies how knowledge is shared within the team. It occurs primarily through learning by doing practices. As GSBM said, "There is not much time to sit down and show how to do things… the best way to learn is to give tasks. If they have a problem, they ask. If they do well, you give them more challenging tasks. Then they grow." Through this hands-on learning approach, team members not only build technical knowledge but also bind together and develop a sense of shared responsibility. This learning-by-doing is supported by informal mentoring and established support, reflecting the established balance between formal procedures and tacit knowledge.

In summary, MP2 team's shared practice is grounded in structured planning routines, such as collaborative sequencing and logistics coordination, supported by standardized visual tools, follow-up mechanisms, and well-defined task-based delegation. These practices are made effective by facilitative leadership, clear roles, and a balance between formal procedures and tacit knowledge (experience, intuition and creativity). Together, they form an adaptive and reliable system for managing complexity in a high-risk and space-constrained environment.

5.2.4 Summary: MP2 Production Team's Community of Practice

MP2 highlight that production planning is deeply rooted as a shared concern for sequencing, carried out through collaborative planning, formalized through structures yet supported by adaptive expertise. Planning responsibilities are clearly delegated to block managers, who hold full ownership of execution within their scope. Their work is supported by the production manager and informed by the schedule, maintained by PTS. This setup, rather than a reactive approach ensures proactivity, ensures proactivity adapting to works dynamics.

Sequencing is central in production planning as it guides the temporal and spatial alignment of activities. Particularly, the elevator shaft's activities are prioritized, as they define the critical path impacting the whole project timeline. PTS is central in setting priorities and following up each block manager, by keeping progresses and assessing consequences. This continuous follow-up mechanism combined with decentralized detailed planning ensures alignment between plan and execution, rather than remaining a static document.

Structured interdisciplinary coordination forms the social glue of the project organization, bringing together disciplines through structured meetings, informal dialogues, and a shared understanding of dependencies. Coordination is not merely procedural, through its structures its channels knowledge sharing enabling collaboration. Dialogues help align members and manage constraints, supported by leadership that stimulates reflection and mutual engagement.

The practice dimension of the production planning team community is represented by a rich repertoire of tools, routines, and collaborative mechanisms that support smooth execution. Planning is made actionable through clearly defined but flexible systems. These practices are supported by formal delegation, visual communication, empowering leadership and extensive personal experience.

Tacit knowledge and formal procedures coexist in MP2's planning environment. Block managers rely heavily on experience, intuition, and informal learning, especially in high-uncertainty tasks. However, this reliance is balanced with formal tools, like arbetsberedning and others internal standards, which provide consistency and reduce fragmentation. Learning is embedded in doing, with mentorship and progressive task responsibilities, shaping how knowledge is shared on site.

In short, as showed in Table 5, MP2's production planning system operates through a balance of structure and flexibility, delegation and collaboration, and formalization and intuition. These elements sustain the CoP dimensions: sequencing as domain, coordination as community, and routines as practice. Together, they allow the production team to proactively manage the project toward common purpose.

Dimension from Wenger (1998)	Empirical Findings	Main Theme
Domain	Sequencing is the shared concern. It structures planning logic, team roles and goal setting. It provides coordination across blocks and ensures proactive execution.	Production Planning
Community	Through structured formal, such as schedule follow-up, and informal office conversations, block managers engage to align activities and manage interdependencies.	Interdisciplinary Coordination
Practice	Scheduling follow-up, prioritizing critical path, detailed planning, managing tunnel logistics are supported by empowering leadership, visual tools (APD, 3D model), formal delegation, and tacit knowledge toward sequencing.	Sequencing

Table 5 – Summary of MP2 Production Team's Community of Practice

6 DISCUSSIONS

This chapter discusses the empirical findings through the lens of the Communities of Practice framework, structured around its three core dimensions: Domain, Community, and Practice. Through the thematical comparison between MP1 and MP2, the discussion explores how knowledge sharing and interdisciplinary coordination influence production planning. The chapter then synthesizes key insights to answer the research questions, reflect on broader organizational strategies and challenges.

6.1 Thematic Comparison Based on Three Dimensions

Drawing on the empirical findings and the theoretical framework, the projects production team's Communities of Practice are defined through the three dimensions of CoP. This section summarizes key findings, compares them, answering research questions fulfilling the research aim.

6.1.1 Domain: Production Planning through Sequencing

The domain of production planning is legitimized in both projects through a shared concern for sequencing. Sequencing practices develop emotional ownership and bind members to a common purpose, legitimizing members in the production planning domain of the Community of Practice (Wenger, 1998).

In MP2 the domain of production is fully legitimized through structured delegations, established routines, formal interactions and consistent leadership support. Though not formally implemented, the project shows readiness for pull-planning due to its proactive and structured planning environment. The setup was established by PM, who noted: *"I think we do lean more or less every day. But without putting a name on it. That is my approach to it. And last time planner is everything you have to do",* echoing Ballard (2000) conception of Lean Construction principles as embedded practices rather than named methods. The readiness for pull-planning here reflects the literature's view on preparation, responsibility and adaptability (Ballard, 2000)

In contrast, MP1 project, despite the recognition of planning practices importance, lacks clear and shared structure to support it. Planning routines remain fragmented, as shaped by individual judgement and experience, undermining proactive execution and weakening collective ownership. This mirrors Gustafsson and Lindahl (2017) who argue that planning in complex environment cannot solely rely on formal processes, but it requires supportive systems for personal judgement and intuition. Moreover, for collaborative methods to succeed, the domain must be legitimized not only through shared concern, but also through mutual understanding, dedicated time and supportive structure, as also Ishdorj et al. (2024) found.

Ultimately, empowerment and psychological ownership depend on leadership, clearly defined boundaries and follow-up mechanism that sustain alignment. Soomro et al. (2024) similarly highlight the importance of shared leadership and structural support in enabling collaborative planning in construction. Without them, planning risks becoming reactive and fragmented, undermining its potential in complex and dynamic project environments.

6.1.2 Community: Interdisciplinary Coordination

Interdisciplinary coordination in both projects form the foundation of mutual engagement that binds individuals into a cohesive production planning team. Through repeated interactions and joint problem-solving, members develop awareness of interdependencies and a sense of shared responsibility. In this way, coordination practices sustain the community dimension of the Community of Practice, legitimizing participation and shaping how collaboration unfolds in the production planning process (Wenger, 1998). Synthesizing the projects addresses the *Research Question 1: How does interdisciplinary coordination happen in production planning processes within project teams?*

Both MP1 and MP2 reveal that interdisciplinary coordination emerges from mutual engagement, however the degree of structure and leadership support significantly shape how it is activated. In MP1, coordination relies heavily on individual initiative and informal dialogues. Without consistent preparation and structured routines, planning discussions often suffer from misunderstandings and poor integration across disciplines. This reflects the fragmentation risk described by Lin and Wang (2019) and Soomro et al. (2024), where disciplinary siloes undermine coordination. In contrast, MP2 demonstrates how structured coordination mechanism, such as regular schedule follow-up, clear delegation of planning responsibilities routines, and facilitative leadership embed knowledge sharing into daily practices. These mechanisms help bring to light interdependencies and make siloed knowledge visible, enabling smooth and effective collaboration, boosting individual empowerment. Also Ishdorj et al. (2024) supported that clear structure helps enhance knowledge sharing within teams.

In summary, interdisciplinary coordination in production planning depends on:

- a strong sense of mutual responsibility and shared project ownership,
- visual tools that provide a common framework supporting and enabling shared understanding,
- empowering leadership that encourages reflection, inquiry and active participation.

These elements reflect key enablers of collaboration discussed by Soomro et al. (2024) and Ishdorj et al. (2024). In MP2, they are embedded in the organizational culture, in fact they promote proactive dialogue, surface knowledge silos, and facilitate collaboration across disciplines. In MP1, the absence of such mechanisms results in fragmented planning and excessive reliance on informal routines, limiting the ability to coordinate effectively (Rathnayake et al., 2023).

Ultimately, coordination shifts into collaboration when CoP are reinforced by structured routines, guided by reflective and facilitative leadership, structured interactions and everyday use of visual tools, not just as occasional technical references, but as shred planning framework (Hou and Pai 2009).

6.1.3 Practice: Sequencing as a Shared Routine

Sequencing routines constitute the practice dimension of both production team's Communities of Practice. They represent the shared and evolving repertoire through which members engage in production planning, that includes detailed scheduling, prioritization, logistics coordination, and visual communication. Through participation in these practices, members develop mutual understanding, negotiate responsibilities, and coordinate execution. In this way, sequencing routines embody the practice dimension by shaping knowledge sharing, problem solving, and membership development (Wenger, 1998).

Understanding this dimension requires looking at how these practices are enacted and approached by the teams. Rather than describing individual tools or the routines in isolation, the analysis focuses on the underlying principles that shape their use. This perspective draws from the dual nature of production planning, discussed in the literature review, which combines tacit knowledge and formal organizational routines, similarly to what Gustafsson and Lindahl (2017) discussed.

Sequencing illustrates how knowledge becomes operationalized in daily planning and coordination in both projects. However the projects have two distinct planning cultures shaped by different levels of structure, and reliance on tacit knowledge. In MP1, sequencing routines are highly personalized, fragmented and decentered, as they are mostly shaped by tacit knowledge that replace formal structures. Therefore planning practices remain reactive and disconnected, resulting in visual tools and schedules inconstantly interpreted. Ultimately, knowledge sharing, mutual understanding and learning are limited, and in turn sequencing lacks integration across disciplines. In contrast, in MP2, sequencing practices are embedded within a structured system. Established routines, shared visual tools and formal delegation provide coherence and alignment. While managers still draw on tacit knowledge, essential for handling uncertainties, this knowledge is channeled through a commonly understood planning structure. The result is a shared repertoire that supports both flexibility and consistency, enabling the team to proactively respond to dynamic site conditions.

These findings directly respond to *Research Question 2: How does interdisciplinary tacit knowledge sharing happen during production planning in construction project teams?*

Tacit knowledge sharing occurs when shared planning routines create space for collective interpretation, coordination, and problem-solving. In structured environments like MP2, this happens through systematic follow-ups, visual communication, and reflective leadership, which allow individuals to embed their personal insights within a collaborative framework. In less structured contexts like MP1, tacit knowledge remains isolated within individual routines, limiting its ability to become shared or organizationally valuable. This findings are also confirmed by Ishdorj et al. (2024) and Shahzad et al. (2024) who argued that contractors must actively promote and sustain innovative thinking by implementing structured knowledge-sharing mechanisms, creating safe spaces for collaboration.

6.2 From Knowledge Sharing to Proactive Production Planning

Reflecting on the interplay between structure and tacit knowledge across the three dimensions of the CoP helps connect the findings to the research aim, addressing *Research Question 3: How can knowledge sharing practices enable a more proactive approach to production planning?*

The findings show that proactive production planning does not emerge solely from technical routines, but from how knowledge is shared and embedded within a common planning structure. Both projects show that tacit knowledge is the organization's lifeblood, and through its sharing it enables alignment of sequencing routines and coordination of interdependencies. However, its effectiveness depends on the structure that channels it and is measured through mutual understanding and alignment between members.

In MP2, formal mechanisms, such as regular schedule follow-ups, visual tools, and clear delegation, create a stable framework for immediate mutual understanding, making tacit knowledge visible, shareable and actionable. In contrast, in MP1 relies on informal and individualized routines, where mutual understanding is often hindered, knowledge stays siloed, resulting in reactive rather than proactive planning.

The CoP framework highlights production planning as the domain, interdisciplinary coordination as the community, and sequencing as the shared repertoire of routines. Together, they show that proactive production planning emerges from a balanced interaction between tacit knowledge and formal structures, as Gustafsson and Lindahl (2017) argued. In such setting, tacit knowledge is not suppressed or replaced but enabled and aligned through shared structured procedures that allow knowledge to circulate activating learning and coordination. Hence, structured procedures are essential, as they:

- allow for knowledge siloes barriers and interdependencies to emerge,
- clarify and define critical interfaces and responsibilities,
- offer channels for **full mutual understanding** through coordinated planning routines.

When these structures are established, as in MP2, coordination shift into collaboration enabling a proactive planning culture. As Davenport and Prusak (1998) and Nonaka (1998) noted, this kind of knowledge sharing is essential for building organizational knowledge that supports long-term learning and innovation, promoting competitive advantage.

Ultimately, it is the structure that enables proactivity in planning. While all planning practices involve knowledge sharing, only when knowledge is effectively channeled through leadership, widely adopted visual tools (e.g., APD, 3D model), clear delegation and consistent follow-up, it becomes collective and actionable (Soomro et al. 2024). In such conditions, knowledge sharing is the **driver** of proactive production planning.

In short, **channeling knowledge sharing through a proactive structure allows for proactive production planning**. Without this structure, as seen in MP1, tacit knowledge remains siloed, coordination weakens, and production planning reverts to reactive control.

7 CONCLUSIONS

This section concludes this research report summarizing the main findings of the research, highlighting the theoretical contributions and practical implications, reflecting on the limitations and finally suggesting future research directions.

7.1 Knowledge Sharing as a Driver for Proactive Production Planning

This research aims to *understand how knowledge sharing practices enable more proactive production planning within infrastructure project teams.* The study was conducted through a case analysis in two metro project organization in Stockholm. Data was collected through interviews, observations and a questionnaire and thematically analyzed and synthetized through the analytical lens of Community of Practice (Wenger, 1998). This method was complemented with insights from Lean Construction perspectives, Tacit Knowledge and Knowledge Management theories, which together supported the analytical approach and fulfilled the research purpose.

7.1.1 Production Planning through Communities of Practice

The three dimensions of the communities of Practice framework provided a robust lens through which to understand the production planning processes in both projects. Production planning emerged as the central concern that defines the shared domain that build the focus and identity of production teams through sequencing practices. In MP2, sequencing routines are clearly structured and consistently supported by formal delegation, schedule follow-ups and leadership. Such setup allows for proactive planning and emotional ownership. In contrast, MP1's fragmented planning practices, shaped by individual routines and informal coordination, lead to reactive control and limited knowledge sharing. These differences show that sequencing practices only support proactive planning when embedded within a system of shared understanding, accountability and structure.

Interdisciplinary coordination occurs in both projects through formal and informal dialogues. MP2's production team benefits from a structured coordination setup that establish immediate mutual understanding and alignment, supporting mutual engagement. In contrast, MP1 relies on informal interactions and individual initiatives, that are often inconsistent and hinder proactive collaboration. These findings illustrate that mutual engagement must be supported by structured routines, leadership and visual tools that make interdependencies and knowledge siloes visible, in favor of channelled knowledge sharing that allows for proactive production planning.

The dimension of practice is shaped by the routines used to follow the sequencing process, that includes detailed planning, scheduling, logistics coordination and use of visual tools. In MP2, these practices are shared, standardized and supported by visual tools and follow-up mechanisms. In MP1, similar tools exist, however their use is inconsistent and heavily reliant on personal experience. Without a common planning structure, these practices remain isolated and reactive, limiting learning and coordination across the team.

7.1.2 Channeling Knowledge Sharing through Structured Practices

Through the theoretical framework application, the aim has been fulfilled by stating that through a proactive structure knowledge sharing enables proactive production planning.

Precisely, interdisciplinary coordination happens through both formal and informal interactions, but its effectivity depends on immediate mutual understanding, supported by structured routines, empowering leadership and shared visual tools. For mutual adjustments and coordinative planning practices, interactions involve tacit knowledge sharing, that is the core driver for proactive production planning. Ensured by designed structures planned to proactively manage the construction execution through continuous follow-up, shared visual tools and clear delegation.

These structures allow knowledge - lifeblood of organizations - to be shared, circulate and acted upon. Therefore, proactivity is not achieved merely by effective knowledge sharing, but it is achieved when knowledge is collectively understood, aligned and operationalized through structured shared planning practices. If these practices become part of the organizational knowledge through structured learning, they can be transferred across projects leading to a unique large community of practice composed of the contractor production teams. This would benefit the firm, by promoting competitive advantage, where team members homogeneously act and can easily move between projects.

It's important highlight that a practical way to assess the effectiveness of knowledge sharing is to analyze the level of mutual understanding among team members. Mutual understanding reflects whether tacit knowledge has been successfully communicated, interpreted and integrated into planning routines.

7.2 Theoretical Contributions

This research contributes to the theory by connecting Communities of Practice, Knowledge Management, and Lean Construction principles in the context of production planning in infrastructure project-based organizations. The research brings the following theoretical contributions.

- Dual nature of planning: tacit knowledge and formal structured routines. The study demonstrated effective production planning emerging from tacit knowledge and formalized procedures interacting.
- Communities of Practice in planning contexts. Extending the CoP framework to construction production planning the study notes the importance of aligning domain (production planning), community (interdisciplinary coordination) and practice (sequencing) to sustain collaborative work.
- Structure as an enabler of tacit knowledge sharing. The findings underline the enabling role of visual tools, empowering leadership and clarity. They make knowledge boundaries visible, creating space for mutual understanding, interdisciplinary coordination and alignment.

7.3 Practical Implications

This research provides actionable insights for contractor firms involved in infrastructure construction projects. These several practical implications are:

- Alignment between culture and structure when introducing new methods. Implementing collaborative methodologies, such as pull-planning, requires not only tools, but an organizational culture ready to adopt those tools. This culture must include shared responsibility, legitimacy and structured routines.
- Structured interactions ensure alignment. Structured routines allow members to align, as they help ensure mutual understanding.
- Empowering leadership establishes reflection. Planning must be legitimized as a shared, forward-looking function, however the role of leaders is essential to facilitate reflective practices rather than enforce control.
- Visual tools are shared languages, not isolated instruments. Tools like BIM models should be integrated into everyday conversations to promote mutual understanding across disciplines.

7.4 Limitations and Reflection

While the study offers valuable contributions, several limitations must be acknowledged.

- Contextual limitations: the research focuses on two metro projects within the Swedish construction sector, both managed by the same contractor. This limits the generatability of the findings to other national or organizational contexts, also for international contexts.
- Scope of perspectives: Although multiple roles across project organizations were interviewed, client representatives and subcontractors were unrepresented. Their inclusion might have enriched the understanding of coordination dynamics.
- Interpretative nature of qualitative methods: The research is based on interviews, observations and thematic analysis. While triangulation and reflexivity were employed, some interpretative bias and observer effect may persist.
- Temporal limitations. The study offers a snapshot of planning dynamics over a limited timeframe. Long-term effects such as post-project learning and methods operationalized were not captured.
- Pull-planning insights remain exploratory. As pull-planning was not fully implemented in either projects, the findings reflect observed challenges and inferred lessons rather than post-implementation evaluations.

7.5 Suggestion for Future Research

Building on the findings of this study, future research could investigate how digital visualization tools support collaboration rather than limit it. Also future studies could examine onboarding practices in other infrastructure sectors, to better understand how structured learning support early integration. Finally, future research could study the role of empowering leadership and how it shapes team collaboration, mutual understanding and proactive planning behaviors on dynamic project environments.

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APPENDIXES

The following two sections follow speculative reflections drawn from theoretical perspectives and empirical findings that could help contractor companies for implementing pull-planning and establishing organizational knowledge:

Lessons for Pull-Planning Implementation:

Pull-planning is, by design, a collaborative method for proactive production planning. As a structured collaboration mechanism, it provides a predefined system that guides sequencing and supports interdisciplinary dialogue promoting ownership across teams. However, its success depends not only its presence within the routines, but on the team's ability to engage with it meaningfully. Pull-planning must be learned, practiced, and supported by a planning culture that embraces iteration, reflection, and joint problem-solving.

The MP1 pull-planning workshop highlighted both the potential and limitations of introducing structured collaborative methods in an unprepared environment. While the goal was to collectively define the sequence for two critical walls, the session became unstructured and unclear due to limited individual preparation, unclear methodology, and absent participants. As previously discussed, MP1's planning culture relies heavily on tacit knowledge and informal coordination and these conditions are incompatible with the demands of pull-planning.

This experience reinforces a key insight from the comparative analysis: structured collaboration cannot be imposed. Collaboration must be supported by existing routines, preparation time, and cultural readiness. Pull-planning assumes that team members are aware of the method and have a clear understanding of their scope, constraints, and dependencies. However, in MP1 during the workshop that baseline was missing, therefore coordination issues were highlighted rather than resolved.

However, a key insight emerged. To introduce and implement new mechanism that change the setup of project organizations, such as pull-planning, a viable stepwise approach support team members to learn and activate the new routines. This process consists of the following steps, that should be followed iteratively and repeatedly:

- Provide a common baseline – to establish awareness of issues
- Block managers perform individual planning – to clarify their scope and constraints,
- Collective refinement – to align interdependencies,
- Present the refined plan – to establish understanding and stimulate reflection
- Reflection and revision – to test and assess individually the plan
- Joint review – to align new changes and stress test the new plan
- Summarize and present the updated shared plan – to ensure final agreement

However, this process requires time and repeated practice. However, these elements are absent in MP1 but embedded in MP2's more structured approach. In contrast to MP2's consistent schedule follow-ups, MP1 lacked the feedback loops needed to make such methods stick. As RIBPM noted, "We have to practice it, that's important […] and you need to have the time to learn pull-planning."

In summary, the lesson from MP1 is not that pull-planning fails, but that it requires strong foundations: **clear delegation, preparatory routines, visual tools, and leadership support**. Without these, collaborative methods remain one-off exercises rather than integrated planning practices.

Planning Process and Knowledge Integrator Role:

The analysis of MP1 and MP2 reveals an organizational gap: the absence of a dedicated role to support the consistent implementation of planning routines across projects. Project teams members in MP1 somehow showed willingness to adopt new collaborative methods, such as pull-planning, nonetheless their application was hindered by time pressure, fragmented routines, and lack of continuous support. The findings showed that learning is iterative and requires space for reflection, reinforcement, and contextual adaptation. These conditions are difficult to maintain without a role entitled to support consistently these processes, especially when members heavily rely on their experience and intuition.

This research proposes a forward-looking solution: the Planning Process & Knowledge Integrator, a cross-project role designed to embed structured planning practices into projects and enable organizational learning. The role implementation directly fulfills the aim of this research, addressing how knowledge sharing can be sustained and operationalized through formal support systems.

The integrator would serve two interconnected functions:

- **Planning Process Supporter**: Assisting project teams in implementing collaborative methodologies, such as pull-planning, by providing structure, facilitating reflection, and ensuring consistent follow-up. This role reinforces the idea that planning is not a merely sequence of tasks, but an ongoing learning process embedded in the team's routine.
- **Knowledge Connector**: Acting as a thread transferring both tacit and formal knowledge transfer across projects. By maintaining continuity in planning tools and team practices, the integrator helps build shared routines and organizational memory, centralizing knowledge by turning local learning into cross-project capabilities.

By supporting planning processes and connecting project's knowledge, this roles integrate procedures and lessons learned from projects. Therefore, this rolw would support not only the technical aspects of planning, but also the interpersonal and cultural conditions that shape how planning practices are adopted and sustained. As the findings show, collaborative planning involves more than coordination, it also depends on trust, communication and shared understanding within the team.

Therefore, by supporting technical planning process and transferring knowledge across projects, the Planning Process & Knowledge Integrator transforms isolated planning tasks into sustained project routines. This figure

responsibilities would be part of a greater scope: build up a community of practice across projects. This would allow for mobility, shared understanding, and aligned approaches across projects. Team members could move between projects without the need to relearn planning approaches, and new employees can be integrated more effectively through standardized learning paths.

In summary, this role translates knowledge management theoretical ambitions into practical strategies. It strengthens the organization's ability to implement collaborative planning, support reflective learning, and cultivate an environment where structured knowledge sharing takes place in real project context.

The following are the three structures that guided the interviews, not all the questions were asked, if already answered by the respondents in other questions.

All the interviews started with the following introductions:

Introduction of myself (5 minutes) (this presentation was usually explicated in the invitation email)

1. Personal presentation: background
2. Mention themes of research: production planning and visualization
3. Ask for consent of recording. (better to do in person to keep less formal?)

Opening of interview to build relationship (10-15 minutes) (one or two of this were asked)

1. How did you end up here? What is your experience?
    a. What are the previous project you worked before and what position did you have?
2. What are your responsibilities here?
3. How many people do you coordinate?
4. How is your daily routine?

Rev1 structure:

How are you daily engaged in in production planning?

- How do you do production planning? How do you organize your work?
- Could you define activities and preparations of activities.
- What preparations do you need to do when planning an activity?
- What are the main challenges?
- How do you solve them and why?
- Is there a formalized way to do your job?
- How much do you act according to your knowledge or by improvisation?
- Why do you need to improvise? And why not?
- Why do you need to act based on your experience/knowledge? And why not?
- How does improvisation affect the overall work?
- Do you use some visual tools planning your work? Why?
- How do you use them?
- Does it facilitate the work? How and why?
- How do you visualize the production planning?
- How do you visualize an activity and the preparations you do for it?

How do you collaborate with the KMA department / time scheduler / block-chef ground, rock and concrete?

- Who do you interact the most with?
- How is the communication happening?
- Describe how a classical meeting happens with them?
- How do you prepare for it?
- What do you bring to the discussions?
- How do you solve issues with your colleagues?
- How do you enable discussions, if needed?
- How do you ensure that there is mutual understanding?

- Have you encountered any situation where a lack of discussion caused a problem in the execution?
- How was it solved?
- Did you use any visual tools?
- Would have you used any visual tools?
- How and why did it benefit?

How do you use visualization when discussing in meetings or informal moments?

- How do you prepare for using visual tools in meetings?
- How do the other prepare for using visual tools?
- What are these visual tools?
- How do you think the tools facilitate discussions? (let them think)
- Why do you use those specific tools? (whiteboard, 3D BIM)
- Why don't you use the other tools? (whiteboard, TV, 3D model….)
- How can you facilitate using visualization during discussions?
- How do the discussion happen with visual tools?
- What are the challenges?

How does the architecture of the room affect the use of visual tools such as the whiteboard?

- How do you and your colleagues dispose around the whiteboard/TV/screen?
- How should it ideally be to use more the whiteboard?
- How would you imagine your ideal meeting room?

Regarding what we discussed what do you think I should have also asked you?

Rev2 structure:

How are you daily engaged in in production planning?

How do you do production planning?

How do you prepare your work?

What preparations do you need to do when planning an activity?

How do you handle a situation where you need another discipline to deliver a work to your discipline?

What are the main challenges?

How do you solve them and why?

How much do you act according to your knowledge or by improvisation?

Is there a formalized way to do your job?

Why do you need to improvise? And why not?

Why do you need to act based on your experience/knowledge? And why not?

How does improvisation affect the overall work?

Do you use some visual tools for your work? Why?

How do you use them?

Does it facilitate the work? How and why?

How do you collaborate with the KMA department / time scheduler / block-chef ground, rock and concrete?

Who do you interact the most with?

How is the communication happening?

Describe how a classical meeting happens with them?

How do you prepare for it?

What do you bring to the discussions?

How do you solve issues with your colleagues?

How do you enable discussions, if needed?

How do you ensure that people understand each other?

Have you encountered any situation where a lack of discussion caused a problem in the execution?

How was it solved?

Did you use any visual tools?

Would have you used any visual tools?

How and why did it benefit?

How do you use visualization when discussing in meetings or informal moments?

How do you prepare for using visual tools in meetings?

How do the other prepare for using visual tools?

What are these visual tools?

How do you think the tools facilitate discussions? (let them think)

Why do you use those specific tools? (whiteboard, 3D BIM)

Why don't you use the other tools? (whiteboard, TV, 3D model….)

How can you facilitate using visualization during discussions?

How do the discussion happen with visual tools?

What are the challenges?

How does the architecture of the room affect the use of visual tools such as the whiteboard?

How do you and your colleagues dispose around the whiteboard/TV/screen?

How should it ideally be to use more the whiteboard?

How would you imagine your ideal meeting room?

Given the situation where you need another discipline to deliver you their work.

How do you handle this situation?

How do you make sure that there is completely mutual understanding?

What type of discussion do you need?

Do you use visual tools?

Why does it happen this way?

What are the challenges?

How would you visualize this planning process?

Regarding what we discussed what do you think I should have also asked you?

Rev3 structure:

Involvement in production planning

1. How are you daily engaged in in production planning?
    a. How do you organize your work?
    b. What are the main challenges?
        i. How do you solve them and why?

Coordination between individuals and disciplines

2. How do you coordinate disciplines/individuals?
    a. Is it more disciplines or individuals that you have to coordinate?
    b. How do you coordinate them?
    c. How do you handle to avoid issues in the execution?
    d. How are you involved in solving problem in production planning?
3. How do you visualize an activity and the preparations you do for it?
    a. Can you walk me through this process?
4. How do you make conversation and discussion happen?
    a. Can you walk me through the process you do?
    b. What's your trick in enabling discussions?
    c. How do you handle a problem due to a lack of discussion and understanding?
    d. How do you help Blockchef understand each other?
        i. How do you use visual for ensuring understanding between people?
        ii. How do visual facilitate the work and why?
5. How do you handle the temporary link between disciplines so that they do not clash?
    a. How do you ensure that when an activity of a discipline ends, another from of another discipline can start?
    b. How do you support disciplines say their needs from other disciplines and make them discuss to find a solution?
        i. Examples?
6. How do you keep a broad overview of the project?
    a. How do you ensure you don't forget some details or some disciplines?
    b. Do you need some support to not fogert some details?
    c. Do you need some support to coordinate disciplines?

i. Do you think pull-planning can help you do so?

Knowledge and Knowledge Sharing

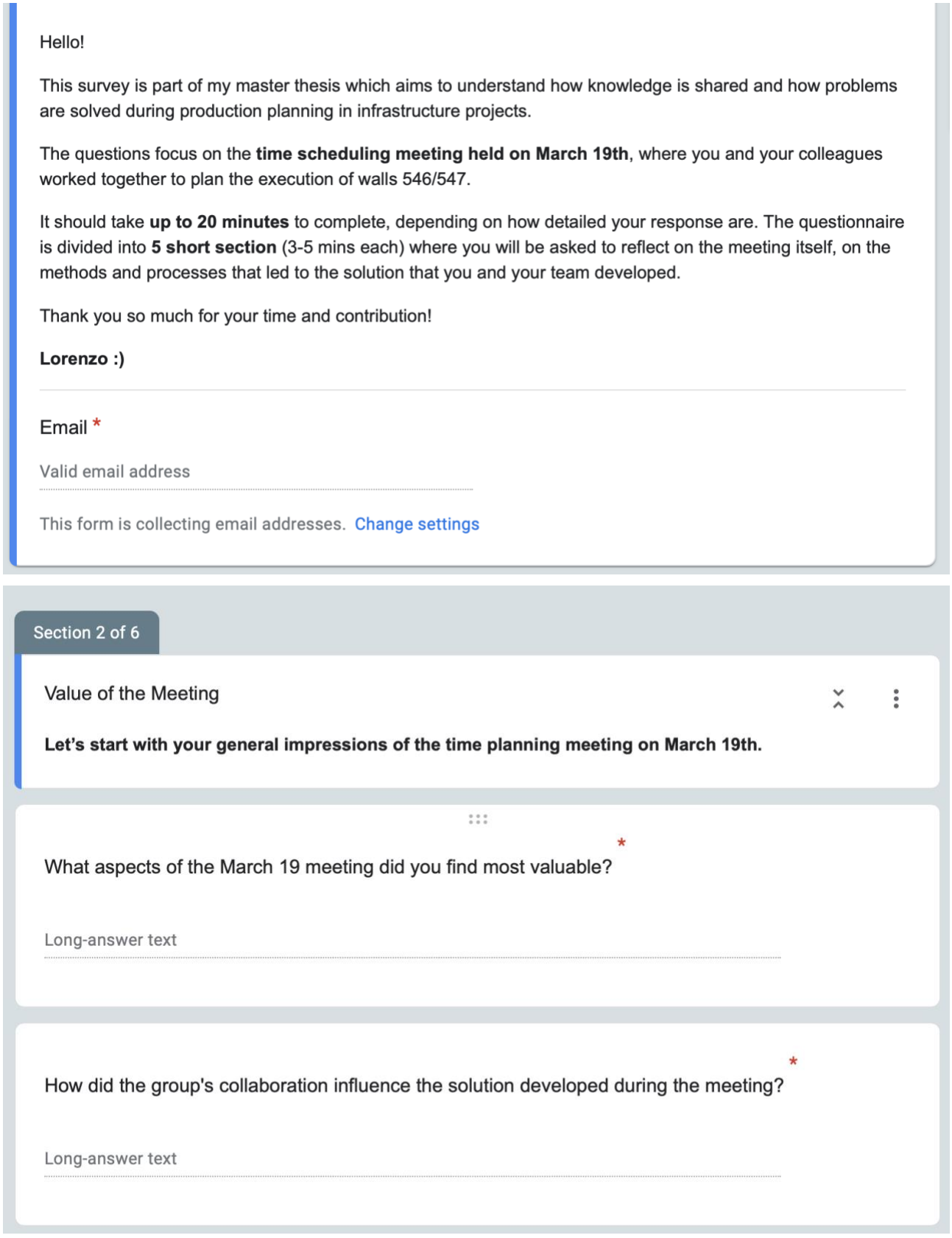
7. What do you rely on when doing your job?
    a. How much do you act according to your experience, improvisation and standards?
    b. Why do you act according to your experience, improvisation and standards?
    c. How does improvisation impact on the overall work?
    d. How do you handle standards that define your way of working?
    e. Is there a standardized way to do your job?
8. How do you handle the diversity within the team?
    a. Diversity in a way that every member has a different background and experience and they act relying on that.
    b. How do you make different knowledge interact?
    c. How do you think knowledge is created?
        i. Sender- receiver or mutual creation through discourses?
    d. Example of the cards (knowledge sharing as playing with uncovered cards)
        i. How do you facilitate the cards be uncovered and put on the table?
        ii. How do you facilitate the understanding between cards (knowledge)?
        iii. What are the challenges?

9. Have you encountered any situation where a lack of discussion caused a problem in the execution?
    a. How was it solved?
    b. Did you use any visual tools?
    c. How and why did it benefit?
    d. What lessons were learned?

10. Regarding what we discussed what do you think I should have also asked you?

Structure of the Questionnaire.

The questionnaire was submitted to the respondents after the pull-planning special meetings.



Hello!

This survey is part of my master thesis which aims to understand how knowledge is shared and how problems are solved during production planning in infrastructure projects.

The questions focus on the **time scheduling meeting held on March 19th**, where you and your colleagues worked together to plan the execution of walls 546/547.

It should take **up to 20 minutes** to complete, depending on how detailed your response are. The questionnaire is divided into **5 short section** (3-5 mins each) where you will be asked to reflect on the meeting itself, on the methods and processes that led to the solution that you and your team developed.

Thank you so much for your time and contribution!

Lorenzo :)

Email *

Valid email address

This form is collecting email addresses. Change settings

Section 2 of 6

Value of the Meeting

Let's start with your general impressions of the time planning meeting on March 19th.

What aspects of the March 19 meeting did you find most valuable? *

Long-answer text

How did the group's collaboration influence the solution developed during the meeting? *

Long-answer text

Section 3 of 6

Problem solving approach

Now, reflect on the approach used by the team to solve the problem during the meeting.

How did the team's approach during the meeting enable you to contribute effectively? *

Long-answer text

How did this approach impact the focus on the project's critical path? *

Long-answer text

What motivated you to share your knowledge or perspectives during the discussions? *

Long-answer text

How did this method enhance the understanding of the other disciplines involved? *

Long-answer text

How has any type of visual tools (e.g. drawings, timelines, 3D model) been used to support the discussions? *

Long-answer text

Section 4 of 6

Awareness of information and project knowledge

This section focuses on how much you and others knew about each other's responsibilities, activities and tasks before and after the meeting. Reflect on yours and other awareness.

How aware were you of other disciplines needs and contributions before and after the meeting? *

Long-answer text

How relevant were the needs and contribution you learned from other disciplines for your work? *

Long-answer text

How aware were the other disciplines of your needs and contributions? *

Long-answer text

How relevant were your needs and contributions for the other disciplines? *

Long-answer text

Section 5 of 6

Level of detail used in discussions

Here, reflect on how detailed your explanations were during the discussions. The explanation can go from higher level of abstraction to lower ones, for example:

- **Processes (e.g., concrete works, ground works)**
- **Activities (e.g., casting concrete, installing equipment)**
- **Single tasks (e.g., setting up formwork, placing reinforcement, removing scaffolding)**

How detailed were you when you had to describe the needs of your work to others? *

Long-answer text

Please provide one example at least

Long-answer text

Why did you choose such particular level of detail? *

Long-answer text

Section 6 of 6

Conclusion and lessons learned

Now reflect on the lessons you learned from the March 19 meeting and drive some conclusions

How do you think this meeting will influence the sequence of wall installations? *

Long-answer text

How were misunderstandings or points of confusion resolved during the meetings? *

Long-answer text

How did this meeting improve your ability to communicate your needs? *

Long-answer text

How has this meeting influenced your approach to production planning within a project team? *

Long-answer text

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